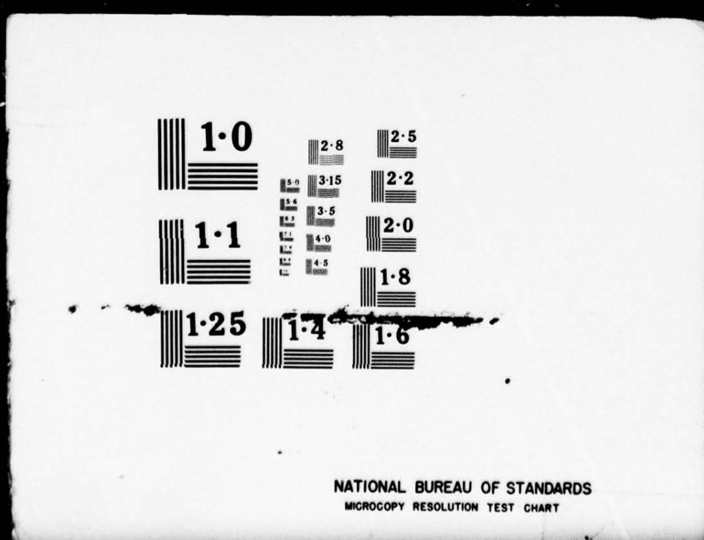
AD-A053 464 SCIENCE APPLICATIONS INC LA JOLLA CALIF F/G 20/8
TIME DEPENDENT AIR TRANSPORT OF RADIATION (TDATR).(U)
JAN 76 L HUSZAR, W A WOOLSON DNA001-74-C-0027

UNCLASSIFIED SAI-76-562-LJ DNA-4061F NL

1 OF 2
ADA
053464

1 OF 2

ADA 053464



AD-E300 192

DNA 4061F

TIME DEPENDENT AIR TRANSPORT OF RADIATION (TDATR)

12

Science Applications, Inc.
P.O. Box 2351
La Jolla, California 92038

January 1976

Final Report for Period 8 August 1973—30 September 1975

CONTRACT No. DNA 001-74-C-0027

APPROVED FOR PUBLIC RELEASE;
DISTRIBUTION UNLIMITED.

THIS WORK SPONSORED BY THE DEFENSE NUCLEAR AGENCY UNDER RDT&E RMSS CODES B325075464 N99QAXPB04512 AND B324074464 N99QAXPB04509 H2590D.

Prepared for
Director
DEFENSE NUCLEAR AGENCY
Washington, D. C. 20305

Destroy this report when it is no longer needed. Do not return to sender.

18 DNA, SBIE/ 19 4061F, AD-E300 192

UNCLASSIFIED

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

REPORT DOCUMENTATION PAGE

READ INSTRUCTIONS BEFORE COMPLETING FORM

1. REPORT NUMBER DNA 4061F	2. GOVT ACCESSION NO.	3. RECIPIENT'S CATALOG NUMBER
4. TITLE (and Subtitle) 6 TIME DEPENDENT AIR TRANSPORT OF RADIATION (TDATR).		5. TYPE OF REPORT & PERIOD COVERED 9 Final Report. [redacted] 8 Aug 73 – 30 Sep 75
		6. PERFORMING ORG. REPORT NUMBER 14 SAI-76-562-LJ
7. AUTHOR(s) 10 L./Huszar W. A./Woolson	17 B045	8. CONTRACT OR GRANT NUMBER(s) 15 DNA 001-74-C-0027
9. PERFORMING ORGANIZATION NAME AND ADDRESS Science Applications, Inc. P. O. Box 2351 La Jolla, California 92038		10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS 16 Subtasks N99QAXPB045-12 and N99QAXPB045-09
11. CONTROLLING OFFICE NAME AND ADDRESS Director Defense Nuclear Agency Washington, D.C. 20305		12. REPORT DATE 11 Jan[redacted]76
		13. NUMBER OF PAGES 106
14. MONITORING AGENCY NAME & ADDRESS(if different from Controlling Office)		15. SECURITY CLASS (of this report) UNCLASSIFIED 12 101p.
		15a. DECLASSIFICATION/DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT (of this Report)

Approved for public release; distribution unlimited.

62704H

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

18. SUPPLEMENTARY NOTES

This work sponsored by the Defense Nuclear Agency under RDT&E RMSS Codes B325075464 N99QAXPB04512 and B324074464 N99QAXPB04509 H2590D.

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

Radiation Transport in Air
TDATR Computer Code
Time-Dependent Prompt Gamma Rays
Time-Dependent Secondary Gamma Rays

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

This report describes the parametrization of time-dependent air transport results for prompt and secondary gamma rays resulting in a computer code which is called Time Dependent Air Transport of Radiation (TDATR). The report describes the generation of the data base for prompt gamma-ray and neutron-induced secondary gamma radiation, the parametrization methods and the command structure of the resulting code which serves as the user's guide for the code. → next page

DD FORM 1 JAN 73 1473 EDITION OF 1 NOV 65 IS OBSOLETE

UNCLASSIFIED

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

388 862

20. ABSTRACT (Continued)

Previous efforts of radiation transport parametrization involved several versions of time independent results under the name: ATR (Air Transport of Radiation).

SUMMARY

This report describes the parametrization of time dependent air transport results for prompt and secondary gamma rays resulting in a computer code which is called Time Dependent Air Transport of Radiation (TDATR). The report describes the generation of the data base for prompt gamma ray, neutron and neutron-induced secondary gamma ray radiation, the parametrization methods for prompt and secondary gamma rays, as well as the command structure of the resulting code which serves as the user's guide for the code.

Previous efforts of radiation transport parametrization involved several versions of a time independent computer code called ATR (Air Transport of Radiation).

CONTENTS

LIST OF FIGURES

LIST OF FIGURES (continued)

LIST OF TABLES

1. INTRODUCTION

This report deals with a time dependent version of the Air Transport of Radiation (ATR) code referred to as TDATR. This version contains the results of the parametrization of dose responses for prompt gamma ray and neutron-induced secondary gamma ray radiation in infinite homogeneous air. Previous versions of ATR(1,2,3) contained time independent parametrizations for neutrons, prompt and secondary gamma rays, X-rays and fission product radiation.

The prompt gamma ray time dependent data base was generated using the MORSE Monte Carlo Code,(4) and the time dependent secondary gamma ray data were generated using the TDA(5) time dependent discrete ordinates transport code. The data base is described in Section 2 of this report.

Section 3 describes the parametrization of six dose responses for each monoenergetic prompt gamma ray source as well as six dose responses for secondary gamma rays due to three neutron source spectra: fission, thermonuclear and 14 MeV.

Section 4 of this report is intended to serve as a user's guide to TDATR. It describes the individual control commands that are needed to execute TDATR. The commands are user oriented, thus, preserving the philosophy of earlier time independent versions of ATR.

The appendices contain pertinent source spectra, dose responses, time parameters, density scaling considerations, the method employed in solving the convolution integral and sample problems.

2. GENERATION OF THE DATA BASE

2.1 INTRODUCTION

This section describes the methods used, problems encountered, and results obtained in generating a time dependent data base of radiation transport in infinite homogeneous air.

Crucial to decisions concerning the methods used to generate the data base and the form of the data base is its intended use. A driving consideration of the TDATR data base is the fact that the data must be scaled to different densities. A detailed description of density scaling of time dependent radiation transport is provided in Appendix B; here, we summarize by indicating the scaling transformation. The time dependent flux $\phi(\bar{r},t)$ from an instantaneous point source at time t at position $\bar{r}$ in an infinite homogeneous medium of density ρ is related to the data base flux computed in density ρ_0 by

$$\phi(\bar{r},t) = K^3\phi_0(\bar{r}_0,t_0)$$

where

$$K = \rho/\rho_0$$

$$|\bar{r}_0| = K|\bar{r}|$$

$$t_0 = Kt$$

Note that time is density scaled. Thus, ideally, the data base should contain a relatively fine resolution in time space since an order of magnitude decrease in density results in a decrease in time resolution by the same order of magnitude.

Two time dependent radiation transport codes were considered to perform the necessary calculations to produce the data bases -- the TDA[5] (Time Dependent ANISN) Code and the MORSE Monte Carlo Code.[4] The MORSE Code has the advantage that results can be computed in local time defined as the absolute time after source emission minus the time for light to travel from the source to the detector. The TDA Code has the advantage of using less computer time for providing detailed spatial and energy flux descriptions.

The MORSE Code was used for the calculations for prompt photon sources. The TDA Code cannot efficiently resolve the arrival and die away of the prompt photons arriving at a detector with its restriction to absolute time. A typical time resolution for TDA for a detector at 1 km is greater than 10 shakes (1 shake = 1 sh = 10^{-8} seconds) at the pulse arrival time. With a local time calculation, however, such as a MORSE calculation, the clock starts when the uncollided radiation first reaches the detector and the peak can be resolved, typically, in tenths of shakes -- a factor of 100 improvement over TDA.

The TDA Code was used for the calculation of time dependent secondary photon transport. The time dependence of secondary radiation arriving at a detector is driven by the time and energy dependence of the neutron transport. Photons from inelastic neutron interactions arrive on the order of 10^{-6} - 10^{-5} seconds after neutron source emission and capture photons arrive at around 10^{-3} - 10^{-2} seconds and make important contributions out to 1 second. It is necessary to transport the neutrons down to thermal energies. TDA is ideally suited for this calculation because the time resolution available with TDA is sufficient and the code solves for the transport of thermal neutrons more efficiently than by Monte Carlo methods.

Both data bases (prompt photons, secondary photons) represent Green's Functions for the time dependence of the transport. The data bases were generated utilizing a "delta" function source in time. Dose was computed as a function of the energy distribution of the source and a time parameter (local or absolute time). If we denote the data base quantities by $G(E,t')$, the time dependent dose $D(t)$ from a source $S(E,\tau)$ is given by an integral over the source energy and a convolution in time

$$D(t) = \int_0^\infty dE \int_0^t G(E,t')S(E,\tau)\,d\tau$$

where

$$t' = t - \tau$$

The following sections describe the details of the data base generation utilizing MORSE for prompt photon sources and TDA for secondary photons from neutron sources.

2.2 DATA BASE FOR PROMPT PHOTON SOURCES

The MORSE Monte Carlo Code was used to compute the data base of time dependent air transport from prompt photon sources. The same P5, 18 energy group cross sections that were used for the time independent calculations[2] were employed in the time dependent data gase generation. Scalar fluence and five dose responses: tissue, concrete, air, silicon and tantalum were calculated. The energy group structure and dose responses are given in Table A-3. Separate calculations are performed for sources uniformly distributed in each of the 18 energy bands. The air was homogeneous with density 1.11×10^{-3} gm/cc.

The doses were scored on spherical surfaces centered on the source point. Local time was used to record the time dependence. Local time, T_L, is related to the absolute time, T_A, after source emission by

$$T_L = T_A - R/C$$

where R is the radius of the detector from the source and C is the speed of light. Thus, the uncollided radiation for an instantaneous source arrives at $T_L = 0.0$. The doses were resolved into 6 time bins per decade from 10^{-9} to 10^{-4} sec local time.

With P5 expanded cross sections, the MORSE Code utilizes three discrete scattering angles for each group to group energy transfer. When a collision event occurs during the random walk, the outscatter energy group is sampled, then one of the three scattering angles for the specific incoming-outgoing energy group set is selected. A ray-effect phenomenon was discovered in the early time dose rates due to the discrete angle scattering treatment in MORSE.

At times <100 ns, the dose rate computed with the conventional MORSE Monte Carlo Code exhibited nonphysical variations when resolved into six time bins per decade as shown in Fig. 1. The "humps" in the dose rate were attributed to the discrete angle scattering. Single scattered photons are the primary contributor to the early time dose and the correlation between the time of arrival at a detector of singly scattered photons and the discrete scattering angles causes the nonphysical dose rates.

The distance traveled and the time for a single scattered photon arriving at a detector is pictorially presented in Fig. 2. A photon travels uncollided to its first collision site a distance

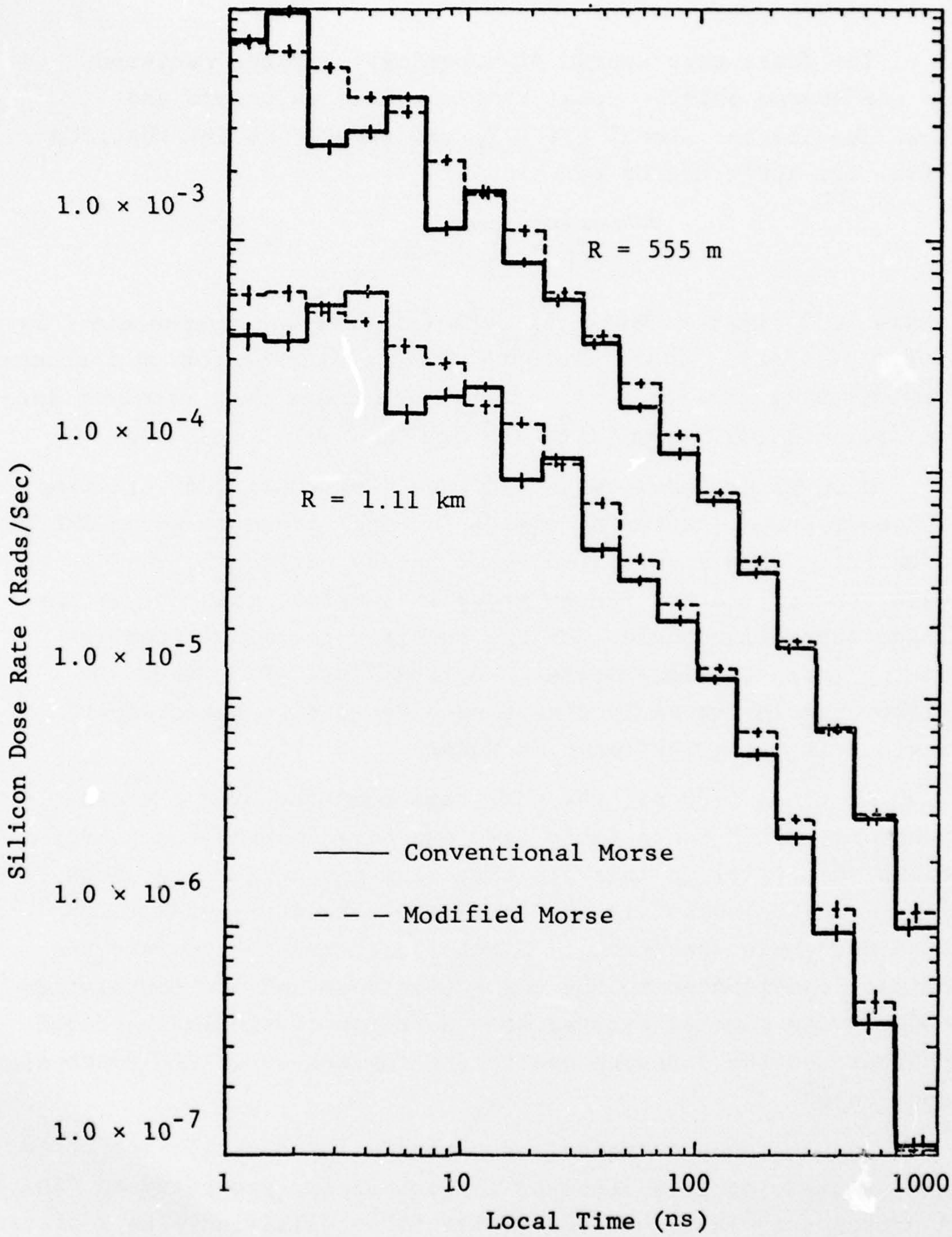


Figure 1. Silicon dose rate at 555 m and 1.11 km of infinite homogeneous air at density 1.11 mg/cm^3 for an 8- to 10-MeV instantaneous photon source.

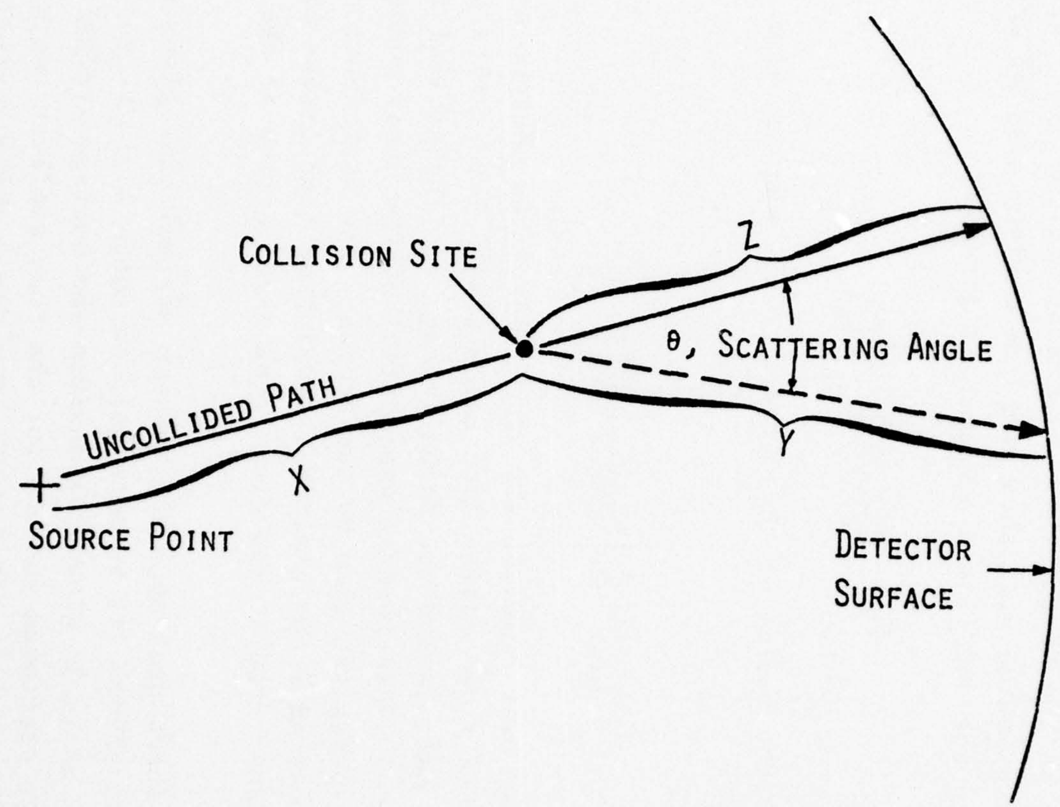


Figure 2. Local time of arrival at detector = (Y-Z)/C.

x from the source point. It then undergoes a scattering through angle θ and travels distance y to the detector. The local time at the detector of the photon arrival is (y-z)/C. Elementary calculus will show that the maximum time of arrival occurs when the uncollided distance is given by

$$x = \frac{R}{\sqrt{2(\cos\theta + 1)}}$$

where R is the radius of the detector. The maximum time of arrival is

$$T_{max} = \frac{R}{C}\left[\left(\frac{2}{\cos\theta + 1}\right)^{\frac{1}{2}} - 1\right] \quad .$$

The arrival times of all singly scattered photons which scatter at a given cosine were calculated. The results of a typical calculation are shown in Fig. 3. The arrival times are weighted by an inverse exponential of the total number of mean-free-paths traveled by the photon. The distribution shows a sharp peak near the maximum arrival time (the latest time a photon scattered at the given cosine can arrive at the detector).

The sharp peak near the maximum arrival time gives rise to the ray effect (if it were uniform there would be no correlation). Table 1 gives the maximum and average arrival times for single scattered photons for the four smallest scattering angles from Group 1 (10-8 MeV). The first three arrival times correspond to the "humps" seen in the data. At later times, more and more contributions come from multiply scattered photons and the ray effect is hidden.

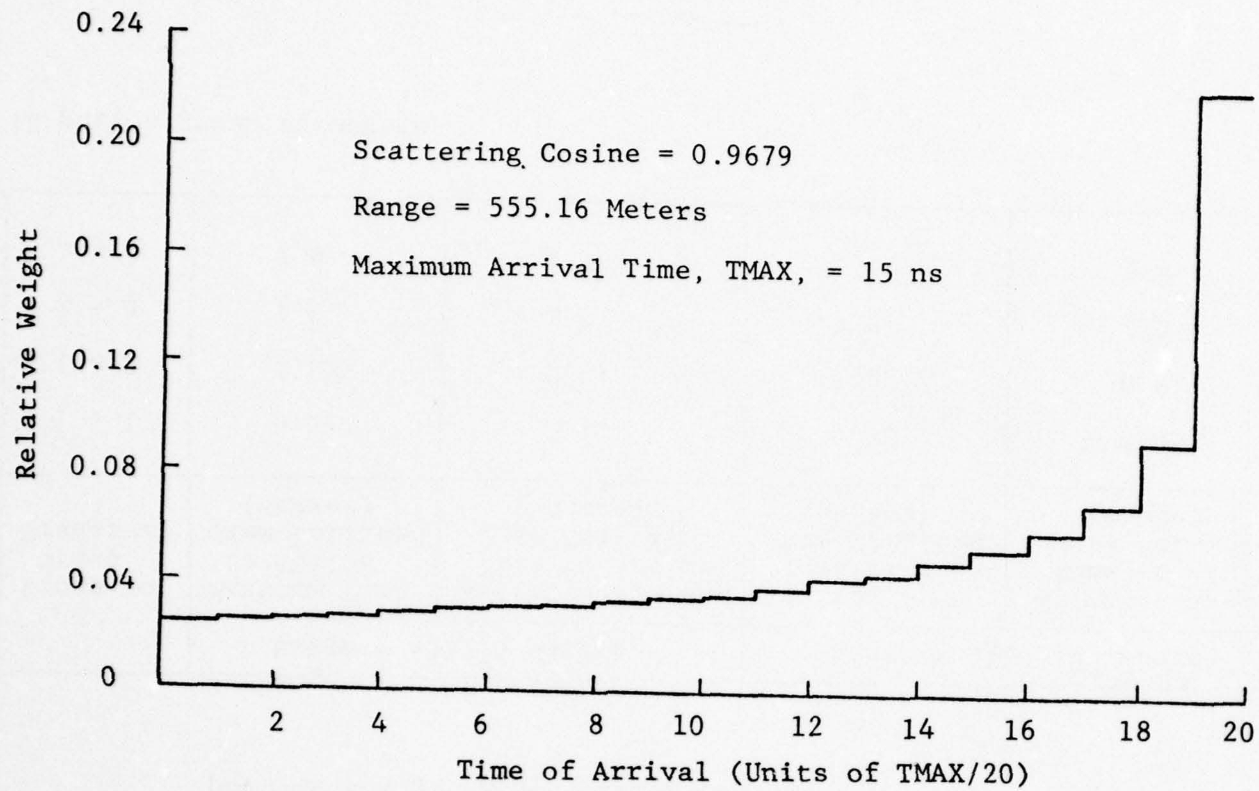


Figure 3. Arrival time distribution at 555 m for photons single scattered at cosine 0.9679. The total cross section before scattering was 2.32×10^{-5} cm^{-1}; after scattering it was 2.84×10^{-5} cm^{-1}.

Table 1. Maximum and average arrival times for single scattered photons for given scattering cosines.

Discrete Scattering Cosine	Group to Group Transfer*	Range = 555.16 Meters		Range = 1110.30 Meters	
		Maximum Time to Arrive Once Collided (Shakes)	Weighted Average Time to Arrive Once Collided (Shakes)	Maximum Time to Arrive Once Collided (Shakes)	Weighted Average Time to Arrive Once Collided (Shakes)
0.9959	1 → 1	0.19	0.13	0.38	0.25
0.9867	1 → 2	0.62	0.41	1.2	0.82
0.9679	1 → 3	1.5	1.0	3.0	2.0
0.9447	1 → 4	2.6	1.7	5.2	3.4

*Standard 18 photon group structure.

The MORSE Code was modified to sample the scattering cosine from the continuous Klein-Nishina distribution for the first scattering only and then continue with the discrete scattering angle selection on subsequent collisions. The results of this computation were compared in Fig. 1 with the previous results. The first-collision Klein-Nishina sampling removed the correlation which gave the non-physical ray effect with the conventional MORSE calculation.

Figure 4 compares the flux at 444 meters computed using the Flair Code[6] with the ATR data base. There is good agreement between the two sets of data. Figure 5 shows the tissue dose rate at several ranges for a prompt gamma ray fission source.

2.3 DATA BASE FOR SECONDARY PHOTONS

The TDA (Time Dependent ANISN) Code was used to generate the secondary photon data base. The TDA Code determines the solution in time space by using the ANISN procedure to solve for the flux at each time step utilizing the flux extrapolation from the previous time step plus any source emission during the time interval.

Proper choices of spatial and time meshes are crucial to a good solution from TDA, since they cannot be selected independently. A problem involving an instantaneous source (delta function) will have a "wave" of uncollided and few within group scattered particles which move through the system at a speed corresponding to the speed of the average group energy. A fixed spatial mesh which is fine enough to cover the wave at all points in the system would require a prohibitive amount of core storage and result in very inefficient, time-consuming calculations, to iterate through the fine mesh as the wave front passes.

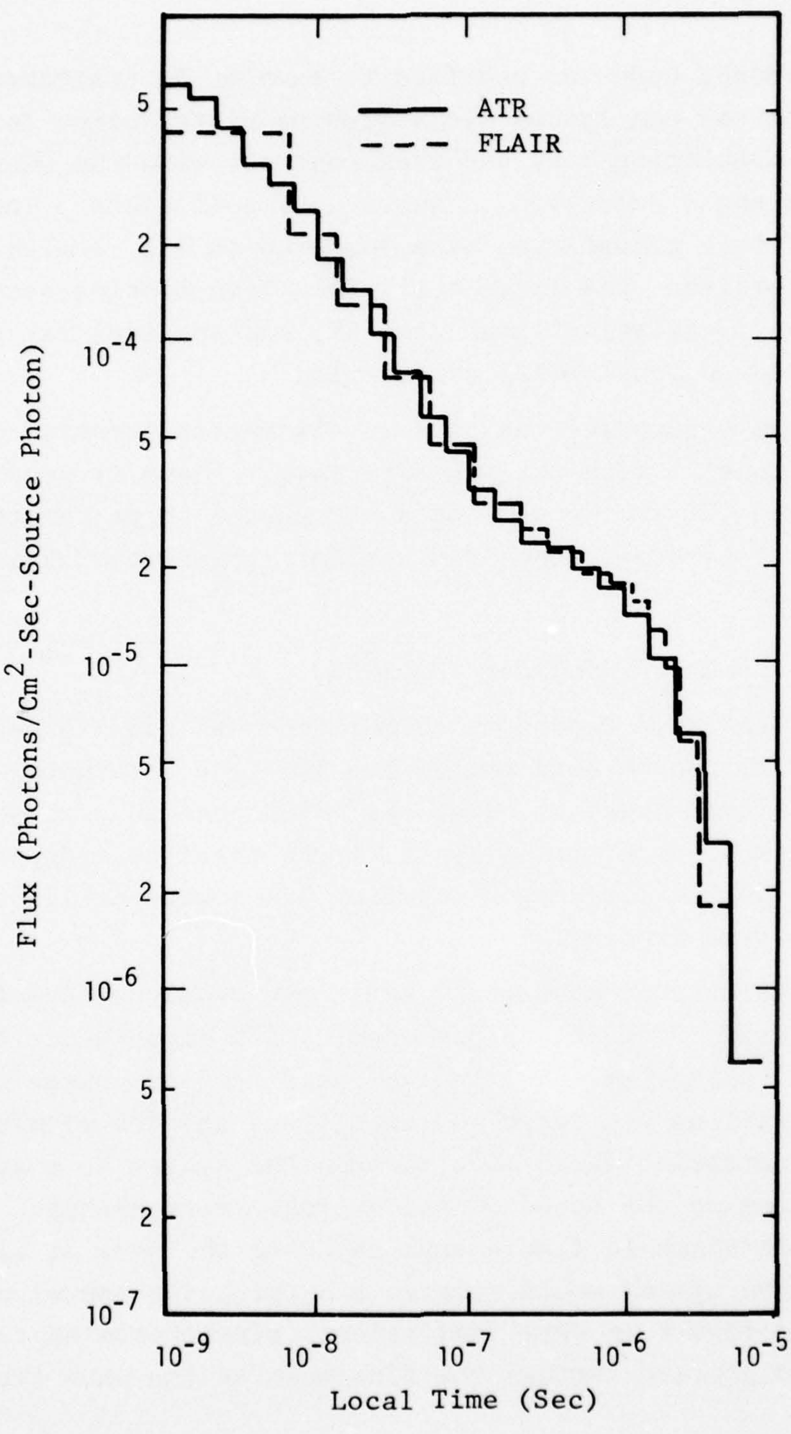


Figure 4. Total flux at 444 meters in air at density 1.11 mg/cc from a 10-8 MeV source band.

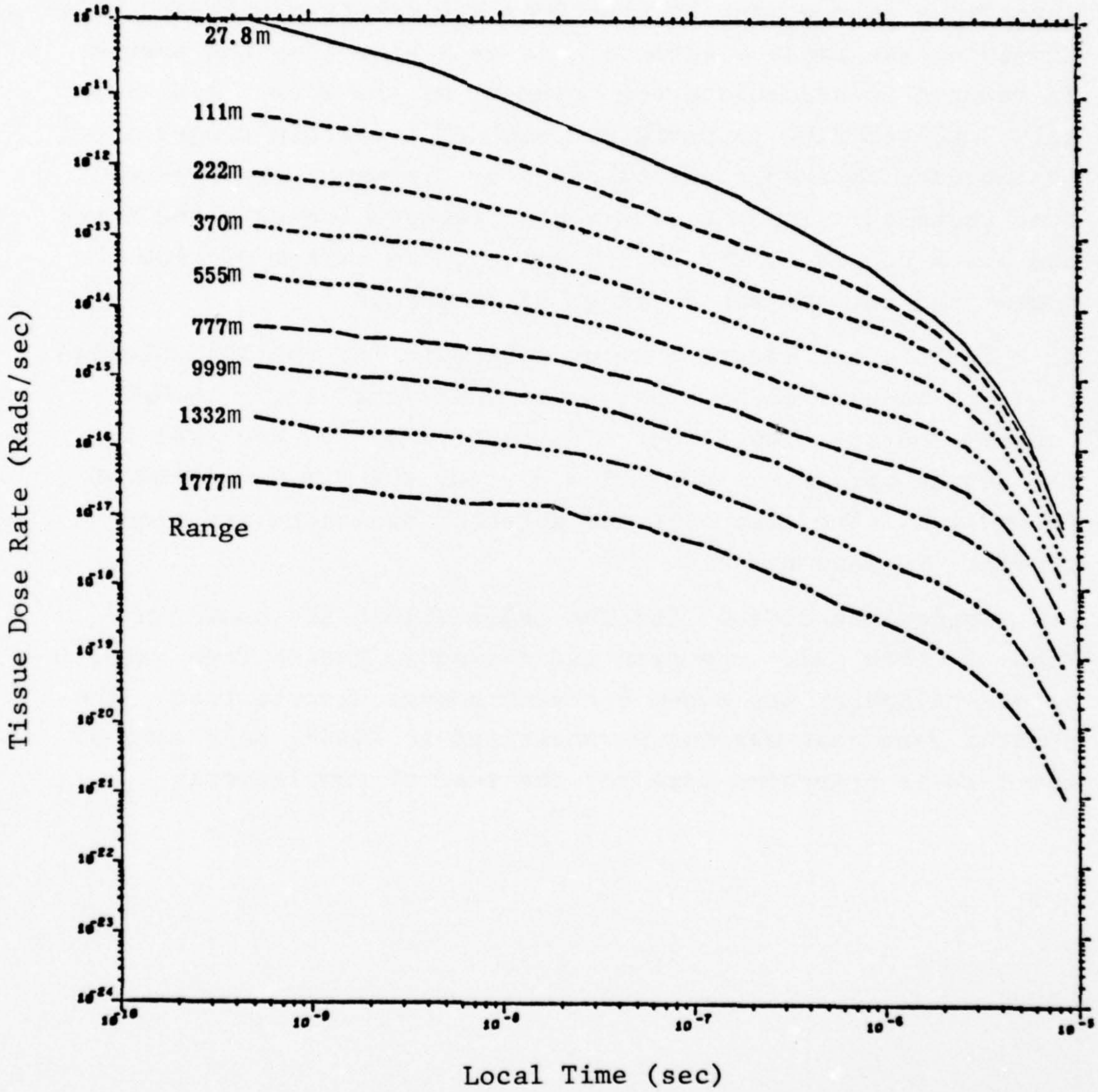


Figure 5. Tissue dose rate from a prompt gamma ray fission source in infinite air.

A time dependent spatial zoning package was incorporated into the TDA Code to permit the use of fine zones near the wave front (where most interactions are taking place) and relatively coarse zones elsewhere. At each time step the system is rezoned to accomodate the movement of the wave. Additionally, the rezoning is performed such that certain ranges input by the user corresponding to detector distances are always zone centered. Input to the zoning package includes the upper and lower bounds on the wave velocity, the number of fine zones, and the number and range of detectors.

Three source distributions were used for the TDA calculations; a weaponized fission, a thermonuclear, and a 14 MeV neutron source. These source distrubtions are identical to the source options in the ATR-4[3] code and are tabulated in Appendix A. The time bins and detector distances are also provided in Appendix A.

Typical results of the TDA calculations are shown in Figs. 6 thru 11. Neutron and secondary photon dose rates at one kilometer are shown for each source distribution. The neutron data base was not parametrized in TDATR, only some of the data is presented here for the sake of completeness.

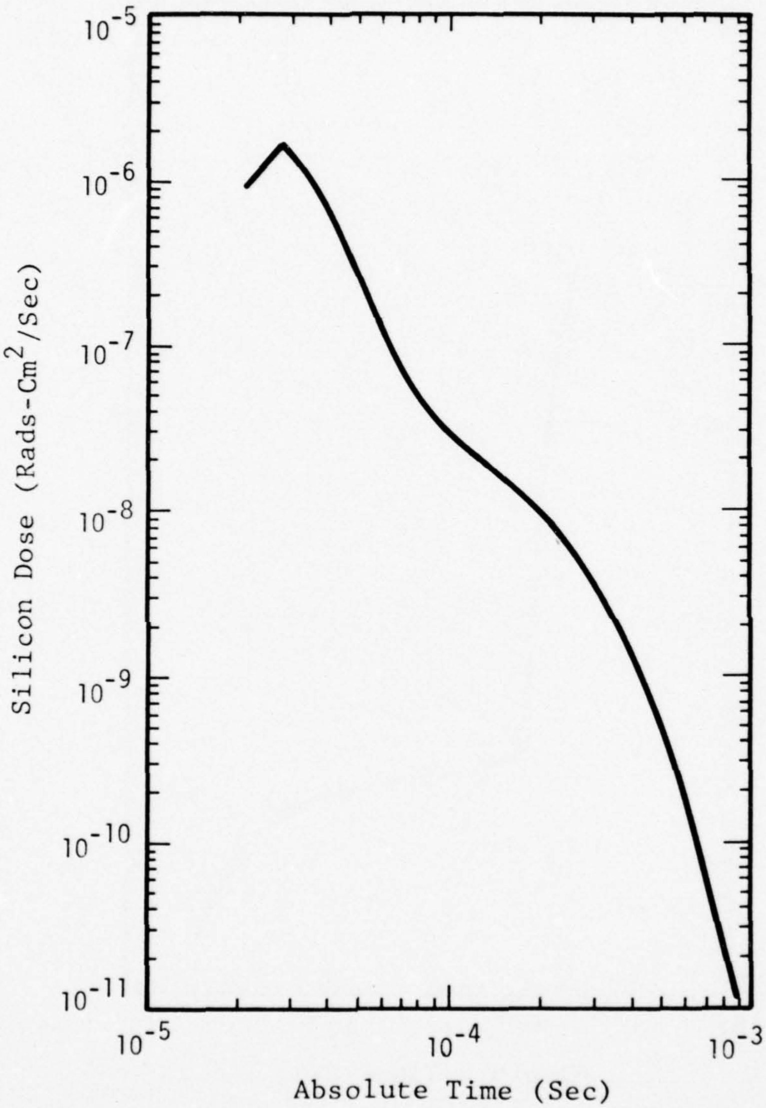


Figure 6. Neutron infinite air silicon dose distribution due to a 14 MeV neutron source with source-target separation of 1 km at a density of 1.11 mg/cm^3.

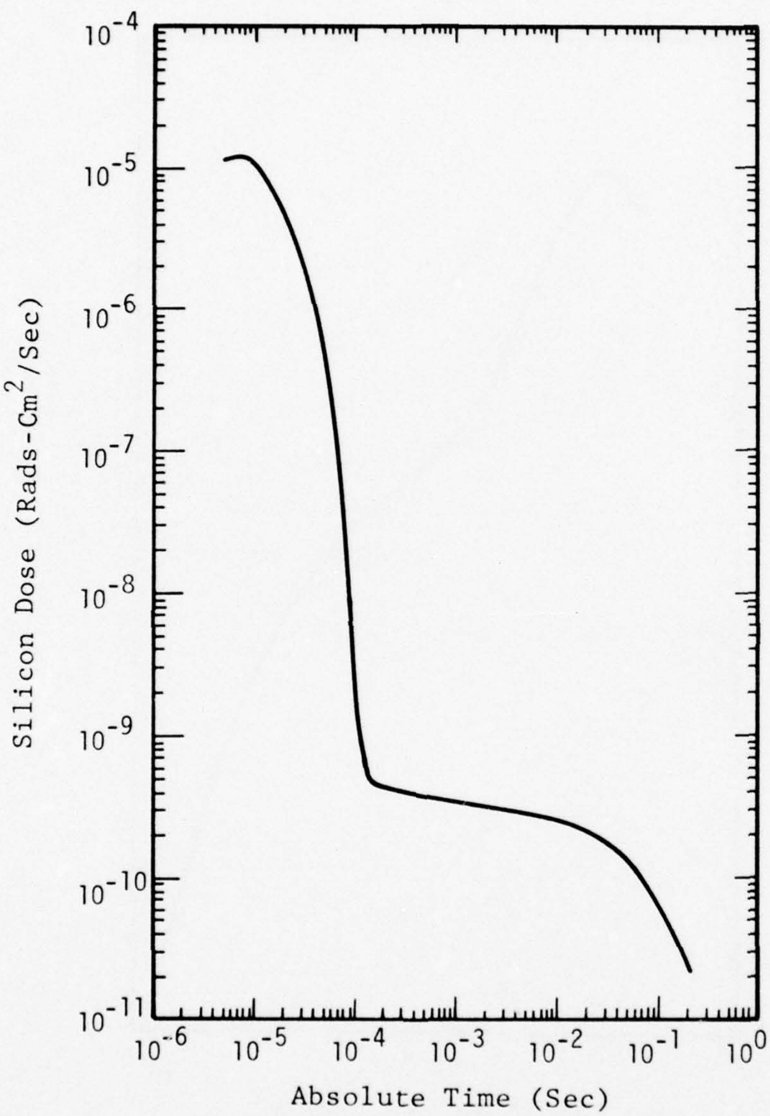


Figure 7. Secondary gamma ray infinite air silicon dose distribution due to a 14 MeV neutron source with source-target separation of 1 km at a density of 1.11 mg/cm^3.

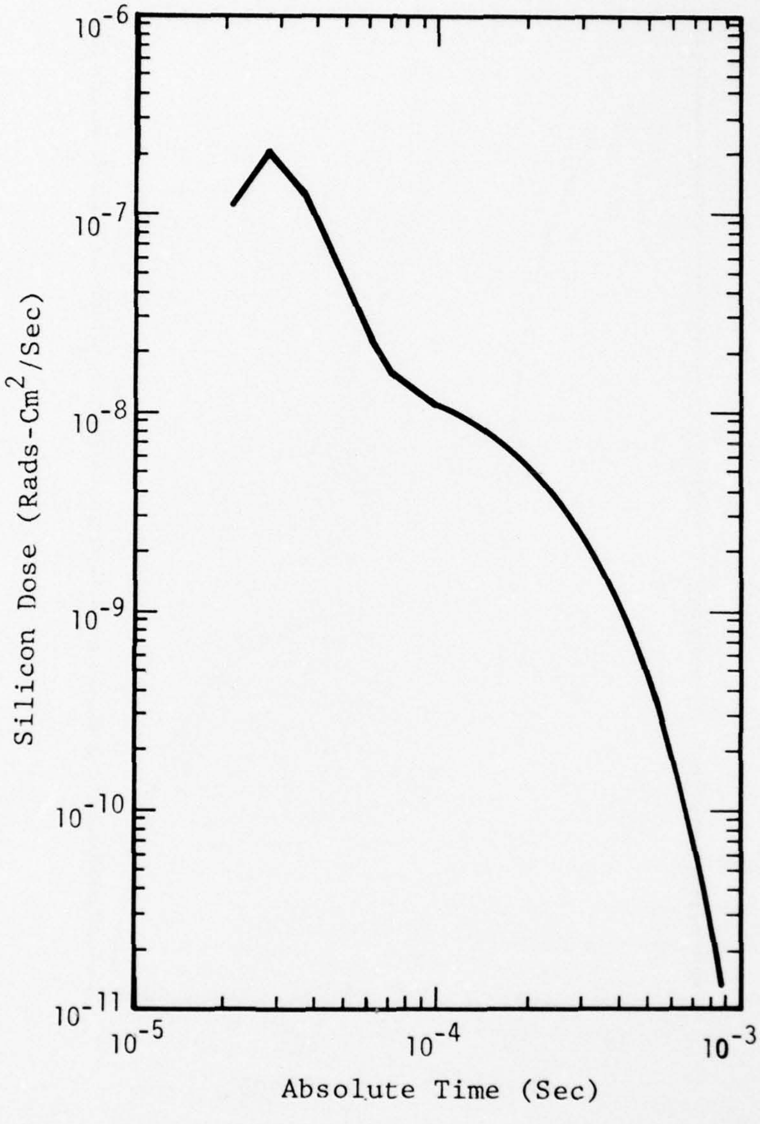


Figure 8. Neutron infinite air silicon dose distribution due to a thermonuclear neutron source with source-target separation of 1 km at a density of 1.11 mg/cm^3.

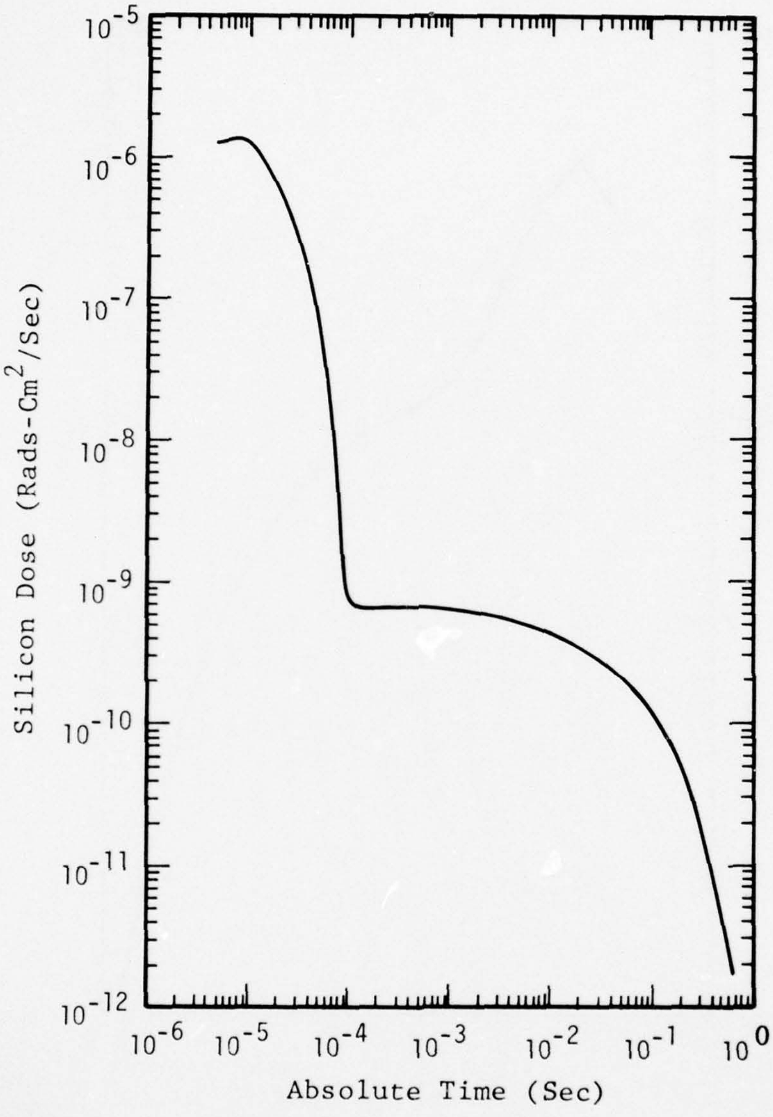


Figure 9. Secondary gamma ray infinite air silicon dose distribution due to a thermonuclear neutron source with source-target separation of 1 km at a density of 1.11 mg/cm^3.

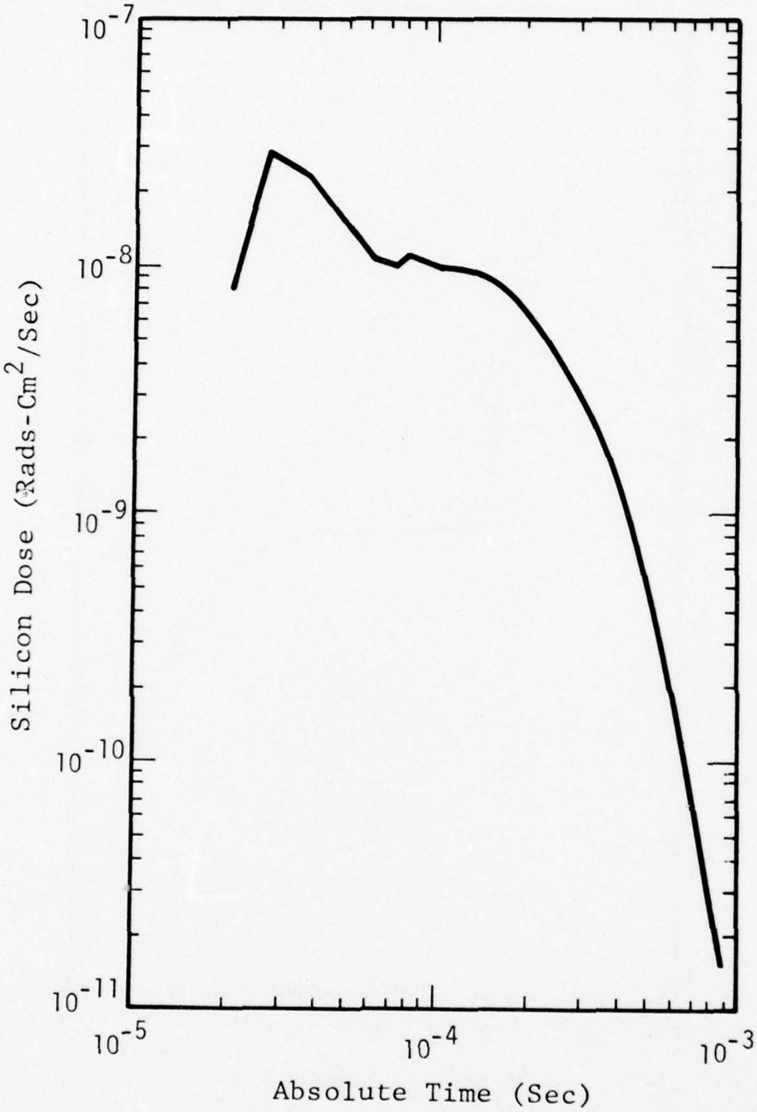


Figure 10. Neutron infinite air silicon dose distribution due to a fission neutron source with source-target separation of 1 km at a density of 1.11 mg/cm^3.

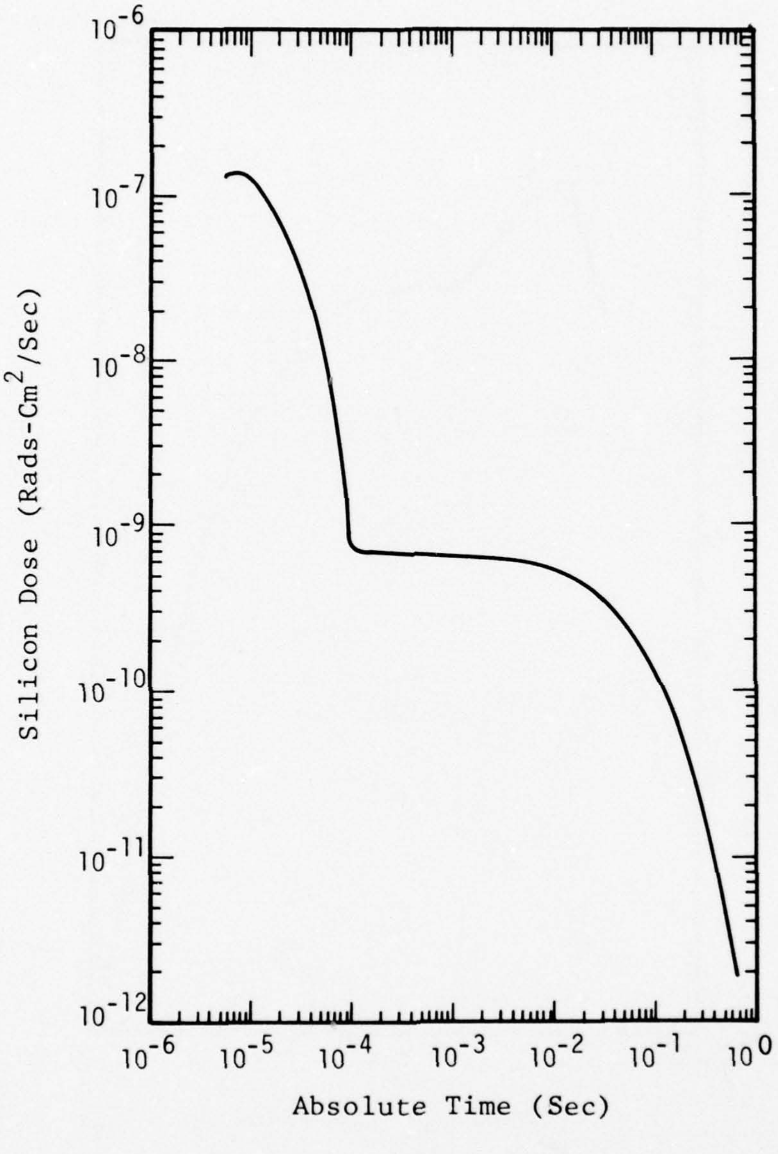


Figure 11. Secondary gamma ray infinite air silicon dose distribution due to a fission neutron source with source-target separation of 1 km at a density of 1.11 mg/cm^3.

3. PARAMETRIZATION OF THE DATA BASE

The data base that was used for the parametrization of the prompt gamma rays consisted of data at 22 ranges out to about 390 gm/cm^2 and 25 local time mesh points out to 10^{-5} seconds for the following six responses:

1. Total Fluence
2. Henderson Tissue Dose
3. Concrete Dose
4. Air Dose
5. Silicon Dose
6. Tantalum Dose

There are detector response values in each of the 18 mono-energetic source groups. The dose factors and the source energy breakdown are detailed in Appendix A.

For the secondary gamma rays there were three standard neutron sources that were used and the same six responses were determined for each. The source spectra were:

1. Fission
2. Thermonuclear
3. 14 MeV

The source weight values are detailed in Appendix A for the fission and thermonuclear source; the 14 MeV source represents the data in the 12.2 - 15 MeV neutron source band. The results were determined for 85 ranges out to about 400 gm/cm^2. There were 40 time mesh points in absolute time out to the maximum value of two seconds.

3.1 PARAMETRIZATION OF PROMPT GAMMA RAYS

The data was displayed through various forms of plots both as a function of time as well as range in order to evaluate trends. Since data generated by Monte Carlo techniques result in statistical variations, it was difficult to adequately categorize the information and some averaging through curve fitting was necessary. There were two categories of data: one included the total fluence, Henderson tissue and tantalum dose values and the other contained the remaining three dose responses. The following ratio function was calculated for each of the responses in the first category:

$$R_i(E_j,t_k,\rho_\ell) = \frac{D_i(E_j,t_k,\rho_\ell)}{D_i(E_{j0},t_k,\rho_\ell)}\ , \ j \neq j_0;\ j_0 = 1,9$$

where $D_i(E_j,t_k,\rho_\ell)$ represents the response values (total fluence or dose) as a function of source energy band E_j, time t_k in seconds, range ρ_ℓ in gm/cm^2. The index i has values of 1, 2 or 6 representing the total fluence, Henderson tissue dose or tantalum dose respectively. The index j ranges from 1 to 18 representing one of the 18 monoenergetic source groups. The index j_0 in the denominator is one for j = 2,3,...,8 and nine for j = 10,11,...,18. That is, 16 ratio functions are generated for each response such that source groups two through eight are divided by the first (highest energy) source group and source groups 10 through 18 are divided by the ninth source group. The indices k and ℓ appear simply to indicate that t_k and ρ_ℓ are time and range parameter variables.

The ratio function was then curve fitted according to the following relationship:

$$\ln \left[R_i(E_j, t_k, \rho)\right] = a_0 + a_1\rho + a_2\rho^2$$

where the a_m are the coefficients of the parameterization and the index ℓ has been removed from the range variable to indicate that it is being treated as a continuous variable. Note that indices, i, j and k are being treated as parameters.

The denominator of the ratio function has a considerably more complicated form and it was parameterized separately according to the following relationship:

$$\ln \left[D_i(E_{j0}, t, \rho_\ell)\right] = b_0 + b_1\tau + \frac{b_3}{(C_1 - \tau)} + b_4 \sqrt{-(J+C_2)/C_3}$$

$$+ b_5\tau^2 + b_6\tau^3$$

where

$$\tau = \ln t, \; C_1 = -10.82, \; C_2 = 10.0, \; C_3 = 13.0$$

the b_m are the coefficients of the parameterization, $j_0 = 1,9$, and the index k has been removed from the time variable in order to indicate that it is treated as a continuous variable.

The ratio function is evaluated for those sources that require it and multiplied by the denominator of the ratio function. Then, in order to generate $D_i(E_j, t, \rho)$ for $t_k \leq t < t_{k+1}$ and $\rho_k \leq \rho < \rho_{k+1}$, the four values: $D_i(E_j, t_k, \rho_k)$ $D_i(E_j, t_{k+1}, \rho_k)$, $D_i(E_j, t_k, \rho_{k+1})$, $D_i(E_j, t_{k+1}, \rho_{k+1})$ are evaluated and a double interpolation scheme is used.

For the remaining three dose responses: concrete, air and silicon dose, the following ratio function was generated:

$$r_i(E_j,t_k,\rho_\ell) = \frac{D_i(E_j,t_k,\rho_\ell)}{D_2(E_j,t_k,\rho_\ell)} \quad , \; i = 3,4,5$$

where $D_2(E_j,t_k,\rho_\ell)$ represents the Henderson tissue dose response. This ratio function has a rather straightforward behavior in that it was represented by an averaged constant or a series of straight lines as a function of the range parameter. Thus, only one or two coefficients are needed to be stored in order to regenerate the ratio function which is then multiplied by $D_2(E_j,t_k,\rho_\ell)$ to regenerate the $D_i(E_j,t_k,\rho_\ell)$ which are needed for the evaluation of $D_i(E_j,t,\rho)$ as previously described.

3.2 PARAMETRIZATION OF SECONDARY GAMMA RAYS

For secondary gamma rays there was a greater similarity between the various responses than for prompt gamma rays, thus, the responses were more readily categorized.

First, the total fluence was parametrized for all three sources by the following function:

$$\ell n\left[D_1(S_j,t_k,\rho)\right] = a_0 + a_1\rho + a_2\rho^2 + a_3\rho^3 + \frac{a_4}{\rho} + a_5\sqrt{\rho}$$

where $D_1(S_j,t_k,\rho)$ represents the total fluence response for source spectra S_j (j = 1,2,3 representing the fission, thermonuclear and 14 MeV neutron sources respectively), the t_k are the time parameters, ρ is the continuous range variable and the a_m are the coefficients of parametrization.

Then, for the remaining dose responses the following ratio was generated:

$$R_i(S_j,t_k,\rho_\ell) = \left[\frac{D_i(S_j,t_k,\rho_\ell)}{D_1(S_j,t_k,\rho_\ell)}\right]$$

$$* \left[\frac{D_1(S_j,t_k,\rho_{\ell_o})}{D_i(S_j,t_k,\rho_{\ell_o})}\right] , \quad i=2,3,...,6; \; j=1,2,3$$

$$= R_i'(S_j,t_k,\rho_\ell) \; N_i(S_j,t_k)$$

where $\ell_o = 1$.

Figure 12 represents examples of $R_i(S_j,t_k,\rho_\ell)$ for the fission source as a function of range with time being the parameter.

The ratio function, $R_i(S_j,t_k,\rho_\ell)$ was parametrized according to the following scheme. For $i=2$, that is the Henderson tissue dose, the following function was used:

$$\ell n\left[R_2(S_j,t_k,\rho)\right] = a_0 + \frac{a_1}{\rho} + a_2\rho + a_3\rho^2$$

where the a_m are the coefficients of the parametrization. For the remaining dose responses the ratio function was treated as a perturbation of $R_2(S_j,t_k,\rho)$, that is:

$$R_i(S_j,t_k,\rho) = R_2(S_j,t_k,\rho) \; P(S_j,t_k,\rho) \; , \quad i=3,4,5,6$$

where $P(S_j,t_k,\rho)$ is a perturbation function of the range variable that is represented by simple straight line functions of ρ.

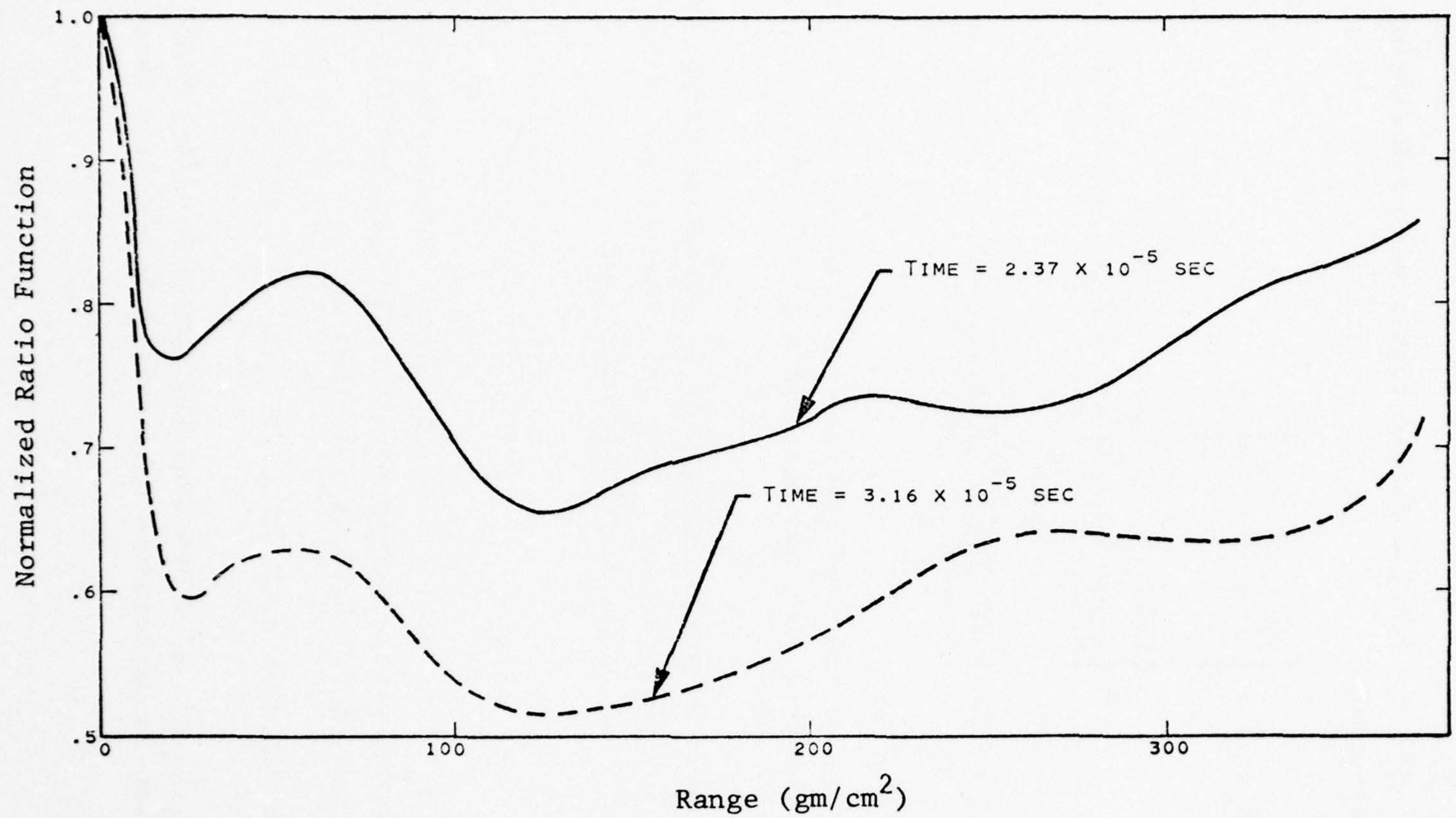


Figure 12. Normalized ratio function for secondary gamma rays for the fission source.

The second term of the ratio function, $N_i(S_j,t_k)$, can be viewed as a normalization function in time, and it ensures that the value of the ratio function is 1.0 at the first range value. Figure 13 shows a representative sample of the time ratio function for the 14 MeV source as a function of time for two dose responses. This term was parametrized separately by the following function of time: let $\tau = \ell n\, t$

$$\begin{aligned} \ell n\left[N_i(S_j,t)\right] &= a_0 + a_1\tau + a_2\tau^2 \\ &\quad + a_3\tau^3 + a_4\tau^4 \quad \text{for} \quad t \le 1.33 \times 10^{-4}\ \text{sec} \\ &= b_0 + b_1\tau \qquad \text{for} \quad t > 1.33 \times 10^{-4}\ \text{sec} \end{aligned}$$

where the a_m and b_n are the coefficients of parametrization.

Thus, the value of $D_i(S_j,t_k,\rho_\ell)$ can be obtained by:

$$D_i(S_j,t_k,\rho_\ell) = \frac{R_i(S_j,t_k,\rho_\ell)\ D_1(S_j,t_k,\rho_\ell)}{N_i(S_j,t_k)}\ , \quad i=2,3,\ldots,6$$

and a double interpolation scheme is used to find the response value at an arbitrary time and range value.

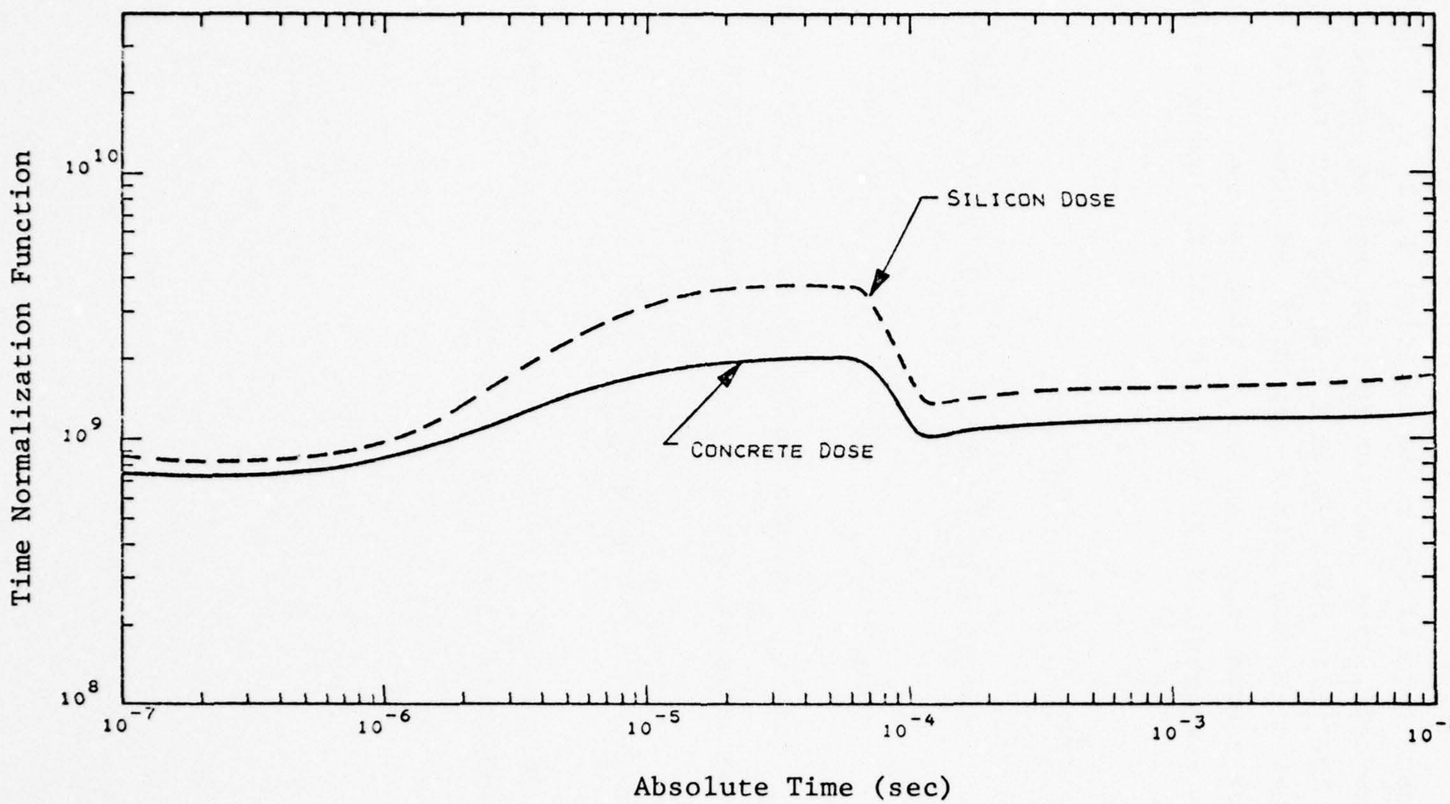


Figure 13. Time normalization function for secondary gamma rays for the 14 MeV neutron source.

4. TDATR COMMAND STRUCTURE

The TDATR command structure is similar to that of ATR with minor modifications and additions. A typical TDATR command is of the following general form:

*<COMMAND WORD>,<UNITS DEFINITION>,<LIST OF VALUES>

All commands must begin with an asterisk. If a TDATR command is too long to fit on a single 80-character line, the command may be continued on subsequent lines not beginning with an asterisk. The restrictions on continuation are that no single part of a TDATR command, such as a number, may itself be split into two lines and there should be at least two numbers (values) on the first card image.

The command word is a mnemonic name for the type of action to be taken. Examples of command words include:

N-SVAL - Source values for neutrons

LTIME - Specifies local time for output

TITLE - Title of a TDATR problem output with the string that follows the first blank after the command word.

A complete list of the commands for TDATR is contained in Table 2. The upper-case letters in the figure indicate specific syntactic elements while the lower-case letters indicate parametric fields. Table 3 contains a short synopsis of the individual commands.

The second field of the general command, the units definition, is delimited by commas. The units definition field, which is optional, serves to explain the meaning of the numbers in the list of values that follows. Typical units include:

Table 2. List of TDATR commands.

1. *N-SOURCE values
2. *G-SOURCE(i)
3. *G-EVAL, units, values
4. *G-SVAL(i_1 i_2 ...), units, values
5. *G-STVAL, units, values
6. *G-GAUSS to B FWHM
7. *G-TIME, units, values
8. *y-NORM value
9. *y-YIELD value
10. *xx, units, value(s)
11. *GROUND, units, value
12. *RESP/z/(i_1 i_2 ...)
13. *LTIME/z/, units, values
14. *ATIME/z/, units, values
15. *TITLE n
16. *EXC
17. *STOP
18. *FIN

y = N or G which stands for either neutrons or gamma rays.

z = G or NG which stands for either gamma rays or secondary gamma rays.

Table 3. Synopsis of TDATR commands.

SOURCE	-	indicates that the ith source option will be chosen for prompt gamma rays or gives the weighting values for neutron sources
EVAL	-	indicates that the energy group boundaries will follow
SVAL	-	indicates that the energy dependent source intensity will be entered
STVAL	-	indicates that the time dependent source intensity component will be entered
GAUSS	-	parameters that define a Gaussian time dependent source
TIME	-	time bins used for time dependent source specification
NORM	-	source normalization value follows
YIELD	-	yield of source
xx	-	indicates the geometry component and associated values will follow
GROUND	-	specifies the ground evaluation
RESP	-	a response function selection for secondary or prompt gamma rays will follow
LTIME	-	the local time bins of interest for time dependent radiation environment will follow
ATIME	-	the absolute time bins of interest for time dependent radiation environment will follow
TITLE	-	alphanumeric character string to be used as a title will follow
EXC	-	an action command to execute the problem specified by prior input
STOP	-	indicates the end of a problem
FIN	-	indicates the end of a TDATR session

MEV - energy values
KEV - energy values
PER SEC - source normalization values
NANO - time values

Specific sets of unit definitions are appropriate for each command, as will be indicated in subsequent sections of this report. A default unit definition has been selected from the set appropriate to each command, and is used whenever the units definition with its surrounding commas is omitted.

The list of values element of an TDATR command is used to specify the numerical data that a command may require. A number in a list may appear in a variety of forms to suit the particular user or problem. For example, some of the forms in which the number 400. may appear are as follows:

400 400. 4.E+2 4E+2 4.+2 4+2 4000-1

At least one number must appear in a list of values element. Two or more numbers are separated from one another by the occurrence of one or more blank characters. Therefore, the user is restricted from specifying a number in which internal blanks appear, or which is split on two or more card images. A further restriction exists upon the magnitude of such numbers: since a number is interpreted as a function of up to three integer parts (a whole part, a fractional part, and an exponent), none of the parts of a number may exceed in magnitude the greatest integer value appropriate to the host machine, nor can the number generated from these three parts exceed the host machine's allowable range of representable numbers.

Section 4.2.1 contains a description of other convenience features associated with the entry of a list of values.

4.1 SOURCE SPECIFICATION

4.1.1 General Source Input Description

The specification of the source distribution for TDATR is complicated by the fact that the prompt and secondary gamma rays were treated rather differently during the parametrization and the source specification must reflect those differences but at the same time must also adhere to the general framework.

Since there are only three possible neutron source selections for which secondary gamma ray data were parametrized, there is no energy dependence as such but a mix of fission, thermonuclear and 14 MeV sources is possible through the use of the *N-SOURCE command which allows for the specification of the three relative weights. The detector response values corresponding to the three source spectra are evaluated and multiplied by the corresponding weights and added together. The weights can be normalized by the use of the *N-NORM command which specifies the total normalization in neutrons/kT. The weapon yield can be specified by the *N-YIELD command which allows the input of the yield in KT of the weapon. There is no time dependence of the neutron source, the weight factors act as a delta-function source.

The prompt gamma ray source specification allows for a full two-dimensional source spectrum, i.e.: specification as a function of time as well as energy is possible. The source component entry as the function of energy is facilitated by the *G-SVAL command and its corresponding structure, if different from the data base, is specified by the *G-EVAL command. There are four different ways that the source values can be defined as a function of time:

1. Delta function
2. Gaussian
3. Separable time-energy functions
4. Individual source values entered into the time-energy source matrix

The differentiation of the various types is specified by the *G-SOURCE(i) command where i is the index of the source types corresponding to one of the above choices. If S(E,t) represents the source spectrum as the function of energy and time, then the energy dependent delta-function values (at t=0) are specified by a special form of the *G-SVAL command.

There is a special time dependent shape of the source spectrum that can be entered via the use of the *G-GAUSS command which is of the following form:

$$f(t) = B\, e^{-\frac{(t-t_o)^2}{2\sigma^2}}$$

where t_o is the mean of the Gaussian, B is the amplitude at $t=t_o$ given by: $B = (a/\sigma\sqrt{2\pi})$ where a is a constant and σ is the variance that is related to the full width at half maximum (FWHM) by the formula:

$$\sigma = \frac{\text{FWHM}}{2\sqrt{2}\sqrt{-\ell n\ .5}} = \text{FWHM}{*}.42466 \quad .$$

The *G-GAUSS command contains the value of t_o in units of shakes, B in units of MeV/second and FWHM in units of shakes. Then TDATR will evaluate σ and will place the time dependent values into the array S(E,t) by weighting the Gaussian values by the energy dependent source values entered via the *G-SVAL command. Also, the value of B will be modified by the time independent energy spectrum from MeV/sec to photons/sec by using the average energy. The time values at which the S(E,t) are evaluated is entered via the *G-TIME command which also applies to the third and fourth type of prompt gamma ray source.

The third type of prompt gamma ray source assumes that the source spectrum is separable in time and energy. That is, the source function S(E,t) can be written as: S(E,t) = g(E)f(t). The function g(E) is strictly a function of energy and is entered via the *G-SVAL command; the energy structure is given by the *G-EVAL command or it defaults to the internal structure. The function f(t) is strictly a function of time and is entered via the *G-STVAL command with values corresponding to source time boundary values entered via the *G-TIME command. The S(e,t) matrix will be filled in by the point by point product of the two functions.

The fourth type of source definition allows for an entry of every matrix element of S(E,t) by the use of the *G-SVAL command that allows for a time index to be specified where the energy dependent values are to be entered. Again, the energy and time structure can be entered via the *G-EVAL and *G-TIME commands respectively.

For prompt gamma rays the commands *G-NORM and *G-YIELD commands also apply; the application of normalization and yield will take on the following form. If N is the value of the normalization in photons/KT, Y is the value of the yield in KT and S'(E,t) is the source matrix in per MEV per second, then the final source spectrum is described by:

$$S(E,t) = \frac{NY\ S'(E,t)}{\iint S'(E,t)\ dE\ dt}$$

where the double integration becomes a double sum since the energy and time boundaries are discrete values corresponding to the discrete values of S'(E,t).

The maximum number of energy, time or source values allowed is arbitrarily limited to 50.

4.1.2 Specific Source Commands

4.1.2.1 *N-SOURCE values

This command specifies the three source weight values separated by one or more blanks that will weight the results of secondary gamma rays from the neutron fission, thermonuclear and 14 MeV sources respectively. If less than three values are entered, then the remaining weights will be zero. There is no unit definition for these values since they are simply used as weighting factors for the respective source contributions. Aside from the optional *N-NORM and *N-YIELD commands, this is the only command necessary for the neutron source definition.

Examples:

*N-SOURCE .25 .25 .5

which specifies a weighting factor of .25 for both fission and thermonuclear sources and a weighting of .5 for the 14 MeV source.

*N-SOURCE 0 0 1

which indicates that only the 14 MeV source is used.

4.1.2.2 *G-SOURCE(i)

This command specifies the intended source spectrum structure of a prompt gamma ray source. The value of i is 1,2,3 or 4 denoting one of the four types of sources that were detailed in Section 4.1.1. Other accompanying commands will specify the value details of the source spectrum. Note the similarity between this command and the one described in Section 4.1.2.1.

Example:

*G-SOURCE(2)

which specifies that a Gaussian-type source will be used for the prompt gamma ray source spectrum and the parameters of the Gaussian will be supplied by the accompanying *G-GAUSS command.

4.1.2.3 *G-EVAL, units, values

units = MEV, KEV. If ",units," is not specified then the default is MEV.

values = energy point or histogram values from low energy to high energy ascending order.

Note that if units are not specified than the surrounding commas must also be omitted. The distinction between point or histogram values will be made by TDATR by counting the number of values entered with a corresponding *G-SVAL command. If the number of values are the same then a point value is assumed, if there is one more energy value than source value then a histogram value structure is assumed, otherwise the code will indicate an error condition.

If this command is not present then the code assumes the internal 18 group structure listed in Appendix A.

Example:

*G-EVAL .01 .03 .1 .4 .8 1.2 1.8 2 4 6 8 10

which represents the energy values for a prompt gamma ray source in units of MeV which is the default.

4.1.2.4 <u>*G-SVAL(i_1 i_2 ...), units, values</u>

$i_1, i_2, \ldots, i_k$ = ordinal indices of time bins into which the values are to be placed separated by one or more blanks. This construct will only be present when the fourth prompt gamma ray source specification is desired because the delta function, Gaussian and separable source functions do not have an explicit time index associated with them. If this construct is not present then the surrounding parentheses must also not be present.

units = PER MEV, PER KEV, PER GROUP; the default is PER GROUP. Note that point source values with a PER GROUP unit specification make no sense and will result in an error condition.

values = energy dependent source values that will be used to compute the actual source values. These values correspond to a given set of energy values provided that the *G-EVAL command is also present, otherwise the values correspond to the internal 18 group energy structure. These values must correspond to the energy values in an order which is low to high in ascending energy order.

If the fourth source option is used then perhaps several commands will be necessary to fill the whole source matrix. The source values corresponding to unspecified ordinal indices will be set to zero:

Examples:

*G-SVAL (1 3 5), PER MEV, .01 1.5 2 2.2 .9 .02

which has the effect of placing the six low energy source values as a function of energy into time bins 1, 3 and 5.

*G-SVAL, PER GROUP, .1 1 2.2 0.5 1-3 2-4

which specifies the energy weights for the six low energy bins for any one of the first three types of sources. Note that the units definition is PER GROUP which is superfluous since it is the default definition.

4.1.2.5 *G-STVAL, units, values

units = one of PER GROUP, PER NANO, PER SHAKE, PER MICRO PER MILLI, PER SEC; the default unit is PER SHAKE.

values = time dependent source values for the separable source spectrum case; i.e. values of f(t) as described in Section 4.1.1. The order of the values is assumed to be from low to high corresponding time values entered via the *G-TIME command.

Example:

*G-STVAL, PER SEC, 2 1.5 1 .3 .1 .01 .001

which specifies seven values corresponding to a time bin structure that is entered via the *G-TIME command.

4.1.2.6 *G-GAUSS t_o B FWHM

The values of t_o, B and FWHM which are the parameters of the Gaussian time dependent source function as detailed in Section 4.1.1. The units of t_o and FWHM are shakes and B has energy units of MeV/sec. The code will evaluate the average energy from the time independent spectrum and modify B to photons/sec.

Example:

*G-GAUSS 100 1 10

which defines a Gaussian time dependent source shape centered at 100 shakes, has an intensity of 1 MeV/sec and is 10 shakes at FWHM.

4.1.2.7 *G-TIME, units, values

units = one of NANO, SHAKE, MICRO, MILLI, SEC; the default unit is SHAKE.

values = time histogram boundary values corresponding to the time dependent dimension of the source specification. The values must be entered from low to high.

Example:

*G-TIME 0 10 21.5 50 100 400 800 1+3 3+3
5+3 1+4 2+4 6+4 1+5 1+6 1+8

which specifies the time boundary values for the prompt gamma ray source in default units (shakes).

4.1.2.8 *y-NORM value

y = N or G representing a neutron source or prompt gamma ray source normalization respectively.

value = total source normalization in particle/KT. There is no default value for total source normalization and if this command is not specified then the source values entered via other commands will be used. The normalization procedure is described in Section 4.1.1.

Examples:

*N-NORM 2+23

which normalizes the neutron source weights to $2x10^{23}$.

*G-NORM 1

which normalizes the total prompt gamma ray source spectrum to one.

4.1.2.9 *y-YIELD value*

y = same as in Section 4.1.2.8.

value = weapon source yield in KT. The default value of the yield is one and there is no explicit unit definition for this command.

Examples:

*N-YIELD 100

which specifies 100 KT as the neutron yield of the weapon.

*G-YIELD .02

which specifies .02 KT as the yield for prompt gamma rays.

4.2 GEOMETRY SPECIFICATION

4.2.1 General Geometry Input Description

The geometry configuration for TDATR is illustrated in Fig. 14 where the component coordinates are:

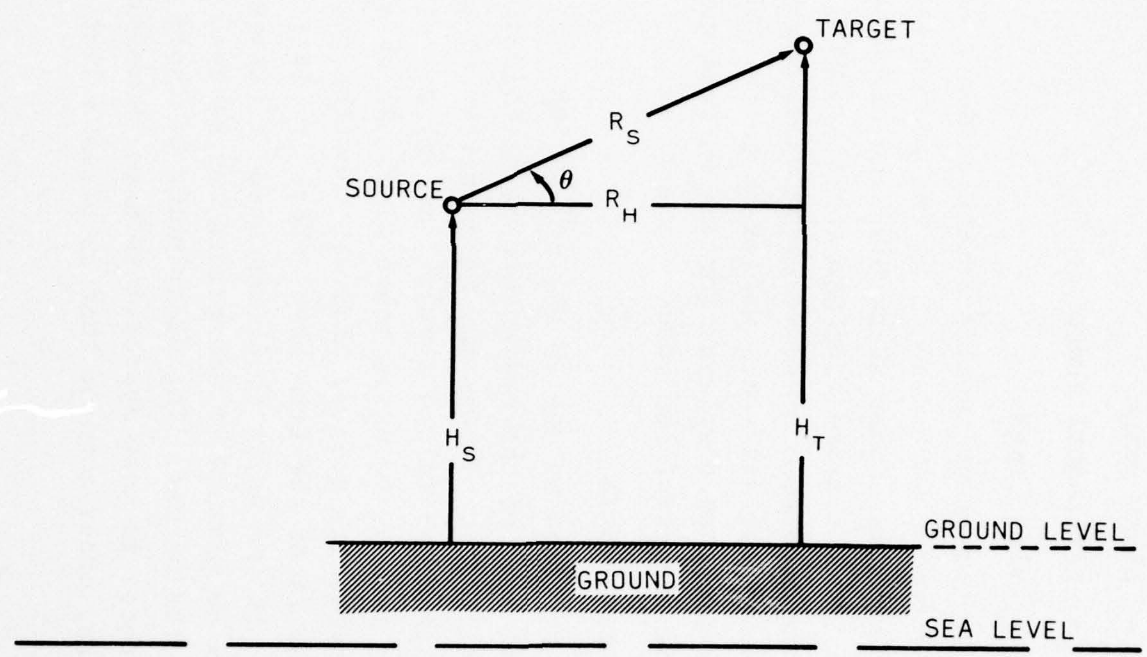


Figure 14. TDATR Problem Geometry

H_S (HS) = source altitude

H_T (HT) = target altitude

R_S (RS) = slant range

R_H (RH) = horizontal range

θ (AN) = slant angle

Three consistent component specifications define a complete geometry configuration with respect to the ground level (as long as one of them is either HS or HT), and the other two components can be calculated from the three. TDATR, therefore, requires the specification of three geometry components one of which may have several different values up to 50. The specified output results are then displayed for the various geometry combinations. The format of the input commands is

*xx, units, values

where xx is replaced by one of HS, HT, RS, RH, AN. The unit options include most of the reasonable units that are appropriate (see Section 4.2.2.1). Values may be specified in a list separated by blanks or in the format: n_1 (n) n_2, signifying values ranging from n_1 to n_2 in steps of n. In this case n_2 must be arithmetically greater than n_1. Another construct for entering values is of the form r*v where r is a repetition factor and v is the value to be repeated r times. Any of the constructs or mixture of constructs may be used for the definition of the values. The description of these two convenient constructs is most appropriate here; however, they can be used with any other command that requires a list of values for input.

Two of the possible geometry configurations result in ambiguities. When RH, RS and HT are specified, there is no inherent information whether HS should be placed above or below HT. In order to resolve the ambiguity the characters

"+" and "-" should be used with the *HT command to indicate that HS should be placed above or below HT respectively (e.g., *HS- 1000). The other ambiguity occurs when RH, RS, and HS are specified and the placement of the target height is in question. In this case, the + and - characters are used with the *HS command to place the target above or below the source respectively. If no character is specified then the default is +.

There is also an option in TDATR to move the ground to a desired altitude. It is effected by the *GROUND command and all specifications involving HS and HT are interpreted relative to the ground. When sequential runs are computed with TDATR, the ground is not automatically reset to zero unless respecified by another *GROUND command or a *STOP command is encountered.

4.2.2 Specific Geometry Commands

4.2.2.1 *xx, units, value(s)

xx = one of RH, RS, HT, HS and AN denoting horizontal range, slant range, target height, source height, and slant angle respectively (Fig. 14).

units = one of M (meters), KM, MILE, YD, KFT, and FT for the distance specification and one of DEG (degrees), RAD (radians), and COS (cosine) for the angle specification. Because of the symmetry of the geometry configuration about the source, the range of admissible angles is from -90° to $+90^{\circ}$. Default unit for the distance specification is M (meters) and for angle it is DEG (degrees).

value(s) = one or more values of the corresponding geometry component. The maximum number of values for any coordinate is arbitrarily fixed at 50.

As mentioned above, three of the geometry commands define a complete TDATR geometry. Each geometry component may have several values in principle; however, the intended use is for two of the components to have single values and the third component to have one or more running values. Another typical use is to have multiple values for two components and one value for the third, in which case the two components with the multiple values will be successively paired and used with the single value of the third component.

There is a special unit definition option (GM) for xx = RS which is allowed if the following geometry configuration is specified: HS, HT, RS. In this case the values associated with the xx = RS command are interpreted as g/cm^2 of the slant range. The GM unit option is restricted to this configuration only.

Examples:

1.
```
*HT +, KM, 1
*RS, KFT, .5  (.5)  10
*RH  100
```

which specifies the target height at 1 kilometer, several values of the slant range starting at .5 kilofeet and ending at 10 kilofeet in steps of .5 kilofeet, and the horizontal range at 100 meters. Note that the different coordinates may be specified in different units. Also, the source altitude will be calculated to be above the target altitude.

2.
```
*HS  2000
*AN, DEG, 10  (10)  80
*RS, KM, 1
```

which specifies the source altitude at 2000 meters, the slant angle ranging from 10 degrees to 80 degrees in steps of 10 degrees, and a slant range of 1 kilometer. The DEG unit specification for the slant angle is superfluous since it is the default unit.

3.
```
*HS, KM, 2
*HT, KM, 2
*RS, GM, 50  120  380  410  550
```

which specifies co-altitude of both source and target at 2 kilometers above the ground and the slant range of 5 different values in units of g/cm^2.

4.2.2.2 *GROUND, units value

units = same as distance specifications in 4.2.2.1.

value = distance of the ground relative to sea level for the TDATR problem geometry.

If this command is not specified then sea level will be used for the ground level. If this command is specified, corresponding HS or HT specifications are interpreted relative to the ground level.

Examples:

1. *GROUND, KM, .5

   which specifies the ground to be at a half kilometer.

2. *GROUND 500

   which has the same effect as Example (1) since the default unit definition is meters.

4.3 OUTPUT RELATED SPECIFICATIONS

4.3.1 General Output Command Description

These commands allow the user to specify the output configuration of results from TDATR. The *RESP command specifies the type of response that is required for output. It can specify any or all of the following:

1. Total Fluence
2. Tissue Dose
3. Concrete Dose
4. Air Dose
5. Silicon Dose
6. Tantalum Dose

The response functions used to generate the doses are listed in Appendix A.

The output times can be specified either as local time by the use of the *LTIME command or as absolute time by the use of the *ATIME command. Only one should be specified but both appear on the output.

The *TITLE command is used to provide the title for the individual TDATR problem and it is useful when several problems are run in a given TDATR session.

There are three control commands that are also described: *EXC, *STOP, *FIN. After the source, geometry and output commands are specified for a TDATR problem, the *EXC command is used to execute the problem and display the results. For subsequent problems only those elements of the problem description are needed to be specified that differ from the previous problem. If radical changes of problem descriptions occur then the *STOP command should be used to reinitialize the parameters of TDATR and the problem must be described in full detail. The *FIN command is used to terminate a TDATR session.

4.3.2 Specific Output Commands

4.3.2.1 *RESP/z/(i_1 i_2 ...)

z = either G or NG representing prompt gamma rays or neutron generated secondary gamma rays respectively.

$i_1, i_2, \ldots$ = response option indices separated by blanks. These are single digit numbers (1 through 6) corresponding to the fluence and dose options described in Section 4.3.1. Any or all of the six options may be present in any order.

Examples:

1. *RESP/G/(1 2)

   which specifies the output of total fluence and tissue dose for prompt gamma rays.

2. *RESP/NG/(3 4)

   which specifies the output of concrete dose and air dose for neutron generated secondary gamma rays.

4.3.2.2 <u>*LTIME/z/, units, values</u>

z = same as in 4.3.2.1.

units = one of NANO, SHAKE, MICRO, MILLI, or SEC representing the possible time units. The default is NANO when the unit definition is not specified in which case the delimiting commas must be absent.

values = local time values from low to high order representing the local time boundary values used for the time dependent output.

Examples:

1. *LTIME/G/ .05 .1 1 10 25 35
   40 60 80 100 300 500 800

   which specifies the output local time boundary steps for prompt gamma rays in nanoseconds which is the default unit specification.

2. *LTIME/NG/,SEC,5-10 1-9 5-9 1-8 5-8
   1-7 6-7 1-6 3-6 6-6 8-6

   which specifies the output local time boundary steps for secondary gamma rays in seconds.

4.3.2.3 <u>*ATIME/z/, units, values</u>

z = same as in 4.3.2.1.

units = same as in 4.3.2.2 including the default parameter.

values = absolute time values from low to high order representing the absolute time boundary values used for the time dependent output.

Only one of *LTIME or *ATIME should be specified for a given TDATR problem per "particle".

Examples:

1. *ATIME/G/,SEC,1-7 1-6 1-5 1-4 3-4
   6-4 103 102 .1 .3 .5 1

   which specifies the output absolute time boundary steps in units of seconds for prompt gamma rays.

2. *ATIME/NG/,MILLI, 1-4 1-3 1-2 .1 .3
   .6 1 10 100 300 500 1000

   which specifies the same values for output absolute time as in Example 1, only the unit specification is different and it applies to secondary gamma rays.

4.3.2.4 *TITLE n

n = up to 74 characters used as a problem description title to identify the output. The title will remain in effect until replaced by a new *TITLE command or cleared by the effects of the *STOP command.

Example:

1. *TITLE SAMPLE TDATR PROBLEM 1

   which would result in the string "SAMPLE TDATR PROBLEM 1" being displayed with the output of TDATR results.

4.3.2.5 *EXC

The effect of this command is to execute the TDATR problem that is specified. The relative order of the previously described commands is immaterial but when this command is encountered the specified problem is executed.

4.3.2.6 *STOP

This command clears all flags and internal buffer areas set up by previous specifications. TDATR is initialized and a complete problem specification must follow this command.

4.3.2.7 *FIN

This command terminates the program with a FORTRAN STOP.

5. REFERENCES

1. L. Huszar, L. F. Nesseler and W. A. Woolson, "User's Guide to Version 2 of ATR (Air Transport of Radiation)," SAI-73-534-LJ, DNA3144Z, April 1973.

2. L. Huszar and W. A. Woolson, "Version 3 of ATR (Air Transport of Radiation)," SAI-75-585-LJ, DNA3819F, July 1975.

3. L. Huszar, W. A. Woolson and E. A. Straker, "Version 4 of ATR (Air Transport of Radiation)," SAI-76-561-LJ, January 1976.

4. E. A. Straker, W. H. Scott, Jr. and N. R. Byrn, "The MORSE Code with Combinatorial Geometry," DNA2860T, May 1972.

5. S. A. Dupree, H. A. Sandmeier, G. E. Hansen, W. W. Engle, Jr. and F. R. Mynatt, "Time Dependent Neutron and Photon Transport Calculations Using the Method of Discrete Ordinates," SAI-70-125, August 1970.

6. W. H. Scott, Jr. and B. L. Colborn, "FLAIR - A Scaling and Folding Code for the Generation of Photon Transport Results in Air," SAI-74-516-LJ, March 1974.

APPENDIX A

TABLES OF PERTINENT PARAMETERS

Table A-1. Source and detector energy boundaries for prompt gamma rays, and detector energy boundaries for secondary gamma rays (MeV).

1.	0.02 - 0.05	10.	1.33 - 1.66
2.	0.05 - 0.1	11.	1.66 - 2.0
3.	0.1 - 0.2	12.	2.0 - 2.5
4.	0.2 - 0.3	13.	2.5 - 3.0
5.	0.3 - 0.4	14.	3.0 - 4.0
6.	0.4 - 0.6	15.	4.0 - 5.0
7.	0.6 - 0.8	16.	5.0 - 6.5
8.	0.8 - 1.0	17.	6.5 - 8.0
9.	1.0 - 1.33	18.	8.0 - 10.0

Table A-2. Source spectra for neutrons.

Group	Energy Boundaries (MeV)	Weapon Fission Source Values (Fraction in Group)	Thermonuclear Source Values (Fraction in Group)
1	1.07(-7)- 2.9(-5)	0	0
2	2.9(5) - 1.01(-4)	0	2.00(-3)
3	1.01(-4)- 5.83(-4)	0	2.40(-2)
4	5.83(-4)- 3.35(-3)	0	1.22(-1)
5	3.35(-3)- 0.111	2.227(-1)	3.65(-1)
6	0.111 - 0.55	1.693(-1)	1.02(-1)
7	0.55 - 1.11	2.159(-1)	8.50(-2)
8	1.11 - 1.83	1.468(-1)	6.20(-2)
9	1.83 - 2.35	1.060(-1)	2.80(-2)
10	2.35 - 2.46	5.743(-3)	5.00(-3)
11	2.46 - 3.01	2.871(-2)	1.90(-2)
12	3.01 - 4.07	5.481(-2)	2.60(-2)
13	4.07 - 4.97	1.177(-2)	1.70(-2)
14	4.97 - 6.36	1.832(-2)	1.80(-2)
15	6.36 - 8.19	1.274(-2)	1.47(-2)
16	8.19 -10.0	7.342(-3)	1.41(-2)
17	10.0 -12.2	0.0	2.56(-2)
18	12.2 -15.0	0.0	7.06(-2)

Table A-3. Dose response functions for gamma rays (rad/(γ/cm^2)).

Group	Upper Energy (MeV)	Henderson Tissue	Concrete Kerma	Air Kerma	Silicon Kerma	Tantalum Dose
1	0.05	8.37(-11)	5.90(-10)	4.40(-11)	4.13(-10)	8.82(-9)
2	0.1	3.90(-11)	1.20(-10)	2.72(-11)	9.75(-11)	6.77(-9)
3	0.2	6.60(-11)	8.00(-11)	5.92(-11)	7.25(-11)	3.57(-9)
4	0.3	1.22(-10)	1.20(-10)	1.11(-10)	1.17(-10)	1.51(-9)
5	0.4	1.77(-10)	1.68(-10)	1.63(-10)	1.65(-10)	9.41(-10)
6	0.6	2.56(-10)	2.42(-10)	2.38(-10)	2.37(-10)	6.70(-10)
7	0.8	3.50(-10)	3.30(-10)	3.26(-10)	3.28(-10)	5.63(-10)
8	1.0	4.45(-10)	4.10(-10)	4.10(-10)	4.10(-10)	5.53(-10)
9	1.33	5.30(-10)	5.05(-10)	5.05(-10)	5.05(-10)	5.85(-10)
10	1.66	6.44(-10)	6.15(-10)	6.15(-10)	6.10(-10)	6.47(-10)
11	2.0	7.35(-10)	7.15(-10)	7.13(-10)	7.12(-10)	7.43(-10)
12	2.5	8.75(-10)	8.40(-10)	8.30(-10)	8.40(-10)	8.73(-10)
13	3.0	1.08(-9)	9.80(-10)	9.52(-10)	9.85(-10)	1.07(-9)
14	4.0	1.27(-9)	1.18(-9)	1.12(-9)	1.20(-9)	1.44(-9)
15	5.0	1.59(-9)	1.46(-9)	1.34(-9)	1.48(-9)	2.01(-9)
16	6.5	1.76(-9)	1.80(-9)	1.60(-9)	1.83(-9)	2.82(-9)
17	8.0	2.07(-9)	2.18(-9)	1.90(-9)	2.28(-9)	3.39(-9)
18	10.0	2.42(-9)	2.65(-9)	2.24(-9)	2.80(-9)	5.34(-9)

Table A-4. Detector local time boundary values for prompt gamma rays.

Group	Time (sec)	Group	Time (sec)
1	0.000	14	1.000(-7)
2	1.000(-9)	15	1.468(-7)
3	1.468(-9)	16	2.154(-7)
4	2.154(-9)	17	3.[illegible]2(-7)
5	3.162(-9)	18	4.642(-7)
6	4.642(-9)	19	6.813(-7)
7	6.813(-9)	20	1.000(-6)
8	1.000(-8)	21	1.468(-6)
9	1.468(-8)	22	2.154(-6)
10	2.154(-8)	23	3.162(-6)
11	3.162(-8)	24	4.642(-6)
12	4.642(-8)	25	6.813(-6)
13	6.813(-8)	26	1.000(-5)

Table A-5. Detector absolute time boundary values for secondary gamma rays.

Group	Time (sec)	Group	Time (sec)
1	0.0	22	1.78(-4)
2	2.15(-7)	23	2.05(-4)
3	4.64(-7)	24	2.37(-4)
4	1.00(-6)	25	2.74(-4)
5	1.78(-6)	26	3.16(-4)
6	3.16(-6)	27	4.22(-4)
7	5.62(-6)	28	5.62(-4)
8	1.00(-5)	29	7.50(-4)
9	1.33(-5)	30	1.00(-3)
10	1.78(-5)	31	1.58(-3)
11	2.37(-5)	32	2.51(-3)
12	3.16(-5)	33	3.98(-3)
13	4.22(-5)	34	1.00(-2)
14	5.62(-5)	35	1.78(-2)
15	6.49(-5)	36	3.16(-2)
16	7.50(-5)	37	5.62(-2)
17	8.65(-5)	38	0.10
18	1.00(-4)	39	0.316
19	1.15(-4)	40	1.00
20	1.33(-4)	41	2.00
21	1.54(-4)		

APPENDIX B

DENSITY SCALING OF THE TIME DEPENDENT BOLTZMANN TRANSPORT EQUATION (BTE) FOR NEUTRAL PARTICLES

In this appendix we prove the general scaling law for the flux that exists between systems having material densities which are distinct but which are constant in space and time. Specifically, let the flux in system 1, $\Phi_1(\bar{r}_1, t_1, E, \bar{\Omega})$, be known, and let it be desired to calculate the flux in system 2, $\Phi_2(\bar{r}_2, t_2, E, \bar{\Omega})$. If the following relationships are true

$$\rho_2 = k\rho_1 \tag{1}$$

$$\bar{r}_2 = k^{-1}\bar{r}_1 \tag{2}$$

$$t_2 = k^{-1}t_1 \tag{3}$$

$$S_2(\bar{r}_2, t_2, E, \bar{\Omega})d^3\bar{r}_2 dt_2 = S_1(\bar{r}_1, t_1, E, \bar{\Omega})d^3\bar{r}_1 dt_1, \tag{4}$$

then we conclude

$$\Phi_2(\bar{r}_2, t_2, E, \bar{\Omega}) = k^3\Phi_1(\bar{r}_1, t_1, E, \bar{\Omega}). \tag{5}$$

To show this we write down the BTE for system 1

$$\begin{aligned} \frac{1}{V}\,\frac{\partial\Phi_1(\bar{r}_1, t_1, E, \bar{\Omega})}{\partial t_1} &= S_1(\bar{r}_1, t_1, E, \bar{\Omega}) \\ &- \bar{\Omega}\cdot\nabla_1\Phi_1(\bar{r}_1, t_1, E, \bar{\Omega}) \\ &- \rho_1\cdot\sigma_t(\bar{r}_1, E)\cdot\Phi_1(\bar{r}_1, t_1, E, \bar{\Omega}) \\ &+ \rho_1\cdot\int d\bar{\Omega}'\int dE'\sigma_t(\bar{r}_1, E')\cdot G(E', \bar{\Omega}', E, \bar{\Omega})\,\cdot \\ &\quad \Phi_1(\bar{r}_1, t_1, E', \bar{\Omega}) \end{aligned} \tag{6}$$

where the notation is conventional.

We now make the substitution indicated by Eqs. (1-4) into Eq. (6). Note the following:

$$\frac{\partial}{\partial t_1} = \frac{1}{k}\frac{\partial}{\partial t_2} \tag{7}$$

$$\nabla_1 = \frac{1}{k}\nabla_2 \tag{8}$$

Also Eq. 4 can be written as

$$S_1(\bar{r}_1, t_1, E, \bar{\Omega}) = \frac{1}{k^4} S_2(\bar{r}_2, t_2, E, \bar{\Omega}) \tag{9}$$

Thus we have

$$\begin{aligned}
\frac{1}{V}\left(\frac{1}{k}\right)\frac{\partial}{\partial t_2}\Phi_1(\bar{r}_1, t_1, E, \bar{\Omega}) = {} & \frac{1}{k^4} S_2(\bar{r}_2, t_2, E, \bar{\Omega}) \\
& - \left(\frac{1}{k}\right)\bar{\Omega}\cdot\nabla_2\Phi_1(\bar{r}_1, t_1, E, \bar{\Omega}) \\
& - \frac{1}{k}\rho_2\cdot\sigma_t(\bar{r}_2, E)\cdot\Phi_1(\bar{r}_1, t_1, E, \bar{\Omega}) \\
& - \frac{1}{k}\rho_2\cdot\int d\bar{\Omega}'\int dE'\sigma_t(\bar{r}_1, E') \\
& \cdot G(E', \bar{\Omega}', E, \Omega)\Phi_1', \bar{r}_1, t_1, E', \bar{\Omega})
\end{aligned} \tag{10}$$

Now if we make the substitution

$$\Phi_2(\bar{r}_2, t_2, E, \bar{\ }) = k^3\Phi_1(\bar{r}_1, t_1, E, \bar{\Omega})$$

into Eq. (10), we get the BTE for system 2 and our conclusion follows.

APPENDIX C

The time dependent radiation environment is determined by a convolution of the time dependence of the source and the time dependence of the radiation transport results obtained for a delta function source. That is

$$\Phi(t) = \int_0^t S(\tau)\, \phi(t-\tau)\, d\tau = \int_0^t f(\tau)\, d\tau$$

where

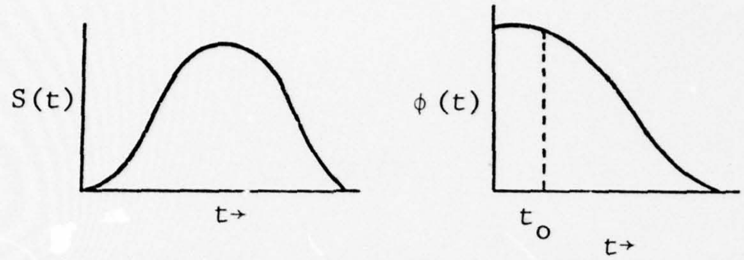
$S(\tau)$ is the time dependence of the source

$\phi(t-\tau)$ is the time dependence of the transport of radiation

and

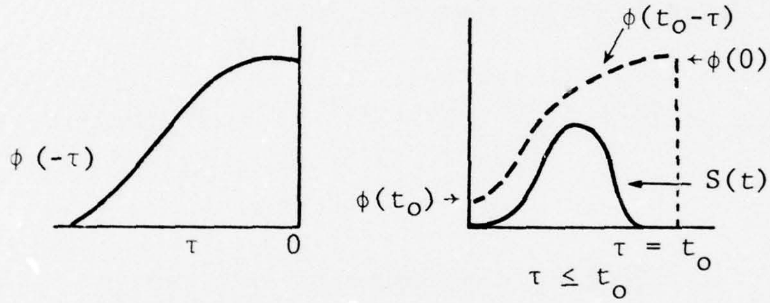
$\phi(t)$ is the desired radiation environment.

The following figures represent some plausible examples of the functions involved in the convolution. The functions $S(\tau)$ and $\phi(\tau)$ represent the source function and the transport function respectively in the first two figures. The third and fourth figures represent the pictorial view of the components of the convolution. The third figure shows the transport function $\phi(-\tau)$ as rotated about the axis and the fourth figure shows the same function shifted by the constant t_o and superimposed on the source function.



given $t = t_o$

$$f(\tau) = S(\tau)\,\phi\,(t_o - \tau)$$



Although both S(t) and φ(t) are treated as histograms in the code, they can be thought of as continuous functions by properly interpolating on the histogram values.

Typically, S(t) is a smooth continuous function such as a Gaussian, and this analysis is based on that assumption. The nature of φ(t) is such that its time resolution, relative to S(t) may be very coarse. Therefore, if we consider the range of integration as being over S(t), for theoretical considerations we can take φ(t) to be slowly varying over the range of S(t) and thus a method of integration considering functions which are no more complicated than S(t) is adequate.

Experience has shown that for most smoothly varying, well-behaved functions the method of gauss quadratures performs very well. The 12-point Gaussian quadrature can be written as:

$$\int_a^b f(t)\,dt = c \sum_{i=1}^{6} w_i \left\{ f\left[a + c(1+x_i)\right] + f\left[a + c(1-x_i)\right] \right\} \qquad (1)$$

where

x_i = interval weights, $0 < x_i < 1$

w_i = amplitude weights, $\sum_{i=1}^{6} w_i = 1$

$c = \frac{b-a}{2}$

The essence of the problem is the representation of the various functions involved. Normally, all three of the functions: $S(t)$, $\phi(t)$, $\Phi(t)$ have different time resolutions and therefore the interpolation method may be important. In order to preserve the maximum overall structure a three-point Lagrangian interpolation is generally adequate. In some cases, however, a two-point (i.e. linear) interpolation may be adequate but for further accuracy a higher order spline interpolation may be required. A parabolic (three point) interpolation is an adequate compromise for most of the problems being considered and is thus utilized in TDATR.

If we let t_i represent the discrete time values and let y_i represent the corresponding function values of $S(t_i)$ or $\phi(t_i)$ then the form of the three-point Lagrangian interpolation is as follows: given points: (t_1,y_1), (t_2,y_2), (t_3,y_3) and a point t such that $t_1 < t < t_3$ and $|t-t_2| \leq \min \{|t-t_3|, |t-t_1|\}$ where $|\ldots|$ denotes the distance norm, then y corresponding to t is given by:

$$y = y_1 \frac{(t-t_2)(t-t_3)}{(t_1-t_2)(t_1-t_3)} + y_2 \frac{(t-t_1)(t-t_3)}{(t_2-t_1)(t_2-t_3)} + y_3 \frac{(t-t_1)(t-t_2)}{(t_3-t_1)(t_3-t_2)} .$$

This scheme forms the parabola defined by the three given points and evaluates the point y corresponding to the given t from the parabola. Since the solution of the convolution integral is an important part of TDATR, it is useful to consider the amount of computer time consumed by this procedure.

The following components of the total time must be taken into account:

T_1: time of interpolation

T_2: time of functional evaluation

T_3: time of integration

The interpolation time can be minimized by keeping track of the interval and if it is the same as before then certain intermediate variables can be saved and need not be computed every time. There are some other overall efficiency considerations which could be exercised but will not be discussed further.

If the floating point multiply of a computer is used as a unit of operation, an add/subtract as a half unit and a divide as four units then an estimate of the computation time can be obtained in units of multiplication times. The following estimates for the three times are obtained by simply counting the number of operations in the above equation and in Eq. (1):

$$T_1 = \frac{14}{2} \text{ (add/subtract)} + 9 \text{ (multiply)} + 3*4 \text{ (divide)}$$

$$= 28 \text{ units}$$

which, in principle, has to be evaluated for every point.

$$T_2 = \frac{4}{2} \text{ (add/subtract)} + 4 \text{ (multiply)} + 4T_1$$

$$= 118 \text{ units}$$

this gives the number of units necessary to evaluate the quantity in Eq. (1) which is in brackets.

$$T_3 = 7\ (\text{multiply}) + 6T_2$$

$$= 715\ \text{units.}$$

There are other overhead operations which will increase the time somewhat but, on the other hand, if there are functional or parametric representations of $S(t)$ and $\phi(t)$ then the interpolation time can be greatly reduced.

For the Univac 1108 this analysis gives about 1.9 msec per one point of $\Phi(t)$. If the interpolation is performed in log space then an extra 20 units must be added to T_1 for the exponential function. This gives a total of 1195 units or about 3.1 msec on the Univac 1108 computer. This would entail that both $S(t)$ and $\phi(t)$ exist in log space as well and that logs need not be taken at every step of the interpolation.

APPENDIX D

TDATR SAMPLE PROBLEMS

The following seven sample problems constitute a representative set of the capabilities of TDATR. The first three examples are concerned with the secondary gamma rays due to different neutron sources. The rest of the problems show examples of prompt gamma rays due to sources of various configuration.

Sample Problem 1

This problem presents the results due to a neutron fission source for secondary gamma rays. Two responses: tissue dose and silicon dose are presented at a geometry configuration of source and target heights at 1 km and a separation of 500 m. The output absolute times are entered in units of seconds.

TDATR SAMPLE PROBLEM 1 - INPUT

```
*TITLE FISSION SOURCE SECONDARY GAMMA RAYS AT 1KM
*N-SOURCE 1 0 0
*HS,KM,1
*HT,KM,1
*RS 500
*RESP/NG/(2 5)
*ATIME/NG/,SEC, 0 4.6-7 1.8-6 5.6-6 1.33-5 2.37-5 4.22-5 6.5-5
 8.65-5 1.15-4 1.54-4 2-4 2.74-4 4.22-4 7.5-4 1.58-3 4-3 1.8-2 5.6-2
 .1 .316 1 1.999
*EXC
```

TDATR SAMPLE PROBLEM 1 - OUTPUT

```
TDATR PROBLEM NUMBER      1           FISSION SOURCE SECONDARY GAMMA RAYS AT 1KM

* * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * *

NEUTRON SOURCE      NORMALIZATION= 1.000E+00 NEUTRONS/KT
    YIELD= 1.000E+00 KT      TOTAL OUTPUT= 1.000E+00 NEUTRONS
    WEIGHTS - FISSION= 1.000E+00  THERMONUCLEAR= 0.000E-01  14MEV= 0.000E-01

* * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * *

TDATR PROBLEM NUMBER      1           FISSION SOURCE SECONDARY GAMMA RAYS AT 1KM

* * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * *
 GROUND LEVEL          0.000KM,    0.000GM/CM**2,   0.000KFT,   0.000MILES
*HORIZ. RANGE  RH=   0.500KM,   55.583GM/CM**2,   1.640KFT,   0.311MILES
 SLANT RANGE   RS=   0.500KM,   55.583GM/CM**2,   1.640KFT,   0.311MILES
 TARGET ALT.   HT=   1.000KM,  116.741GM/CM**2,   3.281KFT,   0.621MILES
 SOURCE ALT.   HS=   1.000KM,  116.741GM/CM**2,   3.281KFT,   0.621MILES
*SLANT ANGLE   AN=    0.000DEGREES (COS= 1.00000)
         *CALCULATED FROM OTHER COORDINATES

* * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * *

    SECONDARY GAMMA  TISSUE DOSE    (RAD/SEC)
```

	ABSOLUTE TIME	LOCAL TIME	UNCOLLIDED	SCATTERED	TOTAL	CUMULATIVE
3	3.700E-06	2.032E-06	0.000E-01	1.680E-17	1.680E-17	6.386E-23
4	9.450E-06	7.782E-06	0.000E-01	1.534E-17	1.534E-17	1.820E-22
5	1.850E-05	1.683E-05	0.000E-01	6.011E-18	6.011E-18	2.445E-22
6	3.295E-05	3.128E-05	0.000E-01	8.320E-19	8.320E-19	2.599E-22
7	5.360E-05	5.193E-05	0.000E-01	9.991E-20	9.991E-20	2.622E-22
8	7.575E-05	7.408E-05	0.000E-01	4.981E-20	4.981E-20	2.632E-22
9	1.007E-04	9.908E-05	0.000E-01	6.370E-20	6.370E-20	2.650E-22
10	1.345E-04	1.328E-04	0.000E-01	6.050E-20	6.050E-20	2.674E-22
11	1.770E-04	1.753E-04	0.000E-01	6.089E-20	6.089E-20	2.702E-22
12	2.370E-04	2.353E-04	0.000E-01	6.068E-20	6.068E-20	2.747E-22
13	3.480E-04	3.463E-04	0.000E-01	5.743E-20	5.743E-20	2.832E-22
14	5.860E-04	5.843E-04	0.000E-01	5.227E-20	5.227E-20	3.003E-22
15	1.165E-03	1.163E-03	0.000E-01	4.676E-20	4.676E-20	3.391E-22
16	2.790E-03	2.788E-03	0.000E-01	4.078E-20	4.078E-20	4.378E-22
17	1.100E-02	1.100E-02	0.000E-01	3.078E-20	3.078E-20	8.688E-22
18	3.700E-02	3.700E-02	0.000E-01	1.659E-20	1.659E-20	1.499E-21
19	7.800E-02	7.800E-02	0.000E-01	6.630E-21	6.630E-21	1.791E-21
20	2.080E-01	2.080E-01	0.000E-01	1.370E-21	1.370E-21	2.087E-21
21	6.580E-01	6.580E-01	0.000E-01	5.023E-23	5.023E-23	2.121E-21
22	1.500E+00	1.499E+00	0.000E-01	1.628E-22	1.628E-22	2.284E-21

```
* * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * *
```

TDATR SAMPLE PROBLEM 1 - OUTPUT (Cont'd)

SECONDARY GAMMA SILICON DOSE (RAD/SEC)

	ABSOLUTE TIME	LOCAL TIME	UNCOLLIDED	SCATTERED	TOTAL	CUMULATIVE
3	3.700E-06	2.032E-06	0.000E-01	2.205E-17	2.205E-17	8.380E-23
4	9.450E-06	7.782E-06	0.000E-01	1.987E-17	1.987E-17	2.368E-22
5	1.850E-05	1.683E-05	0.000E-01	7.687E-18	7.687E-18	3.168E-22
6	3.295E-05	3.128E-05	0.000E-01	1.046E-18	1.046E-18	3.361E-22
7	5.360E-05	5.193E-05	0.000E-01	1.223E-19	1.223E-19	3.389E-22
8	7.575E-05	7.408E-05	0.000E-01	5.943E-20	5.943E-20	3.402E-22
9	1.007E-04	9.908E-05	0.000E-01	7.411E-20	7.411E-20	3.423E-22
10	1.345E-04	1.328E-04	0.000E-01	6.307E-20	6.307E-20	3.447E-22
11	1.770E-04	1.753E-04	0.000E-01	6.349E-20	6.349E-20	3.477E-22
12	2.370E-04	2.353E-04	0.000E-01	6.329E-20	6.329E-20	3.524E-22
13	3.480E-04	3.463E-04	0.000E-01	5.993E-20	5.993E-20	3.612E-22
14	5.860E-04	5.843E-04	0.000E-01	5.457E-20	5.457E-20	3.791E-22
15	1.165E-03	1.163E-03	0.000E-01	4.885E-20	4.885E-20	4.197E-22
16	2.790E-03	2.788E-03	0.000E-01	4.263E-20	4.263E-20	5.228E-22
17	1.100E-02	1.100E-02	0.000E-01	3.222E-20	3.222E-20	9.739E-22
18	3.700E-02	3.700E-02	0.000E-01	1.738E-20	1.738E-20	1.634E-21
19	7.800E-02	7.800E-02	0.000E-01	6.954E-21	6.954E-21	1.940E-21
20	2.080E-01	2.080E-01	0.000E-01	1.439E-21	1.439E-21	2.251E-21
21	6.580E-01	6.580E-01	0.000E-01	5.278E-23	5.278E-23	2.287E-21
22	1.500E+00	1.499E+00	0.000E-01	1.712E-22	1.712E-22	2.458E-21

```
* * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * *
** EXECUTION COMPLETED
```

Sample Problem 2

This problem is the same as the first one except that it presents the results from a thermonuclear neutron source. Since only the source and title changed from Problem 1, those are the only input specifications necessary.

TDATR SAMPLE PROBLEM 2 - INPUT

```
*TITLE THERMONUCLEAR SOURCE SECONDARY GAMMA RAYS AT 1KM
*N-SOURCE 0 1 0
*EXC
```

TDATR SAMPLE PROBLEM 2 - OUTPUT

```
TDATR PROBLEM NUMBER      2           THERMONUCLEAR SOURCE SECONDARY GAMMA RAYS AT 1KM

* * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * *

NEUTRON SOURCE      NORMALIZATION= 1.000E+00 NEUTRONS/KT
    YIELD= 1.000E+00 KT       TOTAL OUTPUT= 1.000E+00 NEUTRONS
    WEIGHTS - FISSION= 0.000E-01  THERMONUCLEAR= 1.000E+00  14MEV= 0.000E-01

* * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * *

TDATR PROBLEM NUMBER      2           THERMONUCLEAR SOURCE SECONDARY GAMMA RAYS AT 1KM

* * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * *
 GROUND LEVEL         0.000KM,    0.000GM/CM**2,  0.000KFT,  0.000MILES
*HORIZ. RANGE RH=   0.500KM,  55.583GM/CM**2,  1.640KFT,  0.311MILES
 SLANT RANGE  RS=   0.500KM,  55.583GM/CM**2,  1.640KFT,  0.311MILES
 TARGET ALT.  HT=   1.000KM, 116.741GM/CM**2,  3.281KFT,  0.621MILES
 SOURCE ALT.  HS=   1.000KM, 116.741GM/CM**2,  3.281KFT,  0.621MILES
*SLANT ANGLE  AN=    0.000DEGREES (COS= 1.00000)
        *CALCULATED FROM OTHER COORDINATES

* * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * *

   SECONDARY GAMMA  TISSUE DOSE   (RAD/SEC)
```

	ABSOLUTE TIME	LOCAL TIME	UNCOLLIDED	SCATTERED	TOTAL	CUMULATIVE
3	3.700E-06	2.032E-06	0.000E-01	1.797E-16	1.797E-16	6.827E-22
4	9.450E-06	7.782E-06	0.000E-01	1.203E-16	1.203E-16	1.609E-21
5	1.850E-05	1.683E-05	0.000E-01	4.094E-17	4.094E-17	2.035E-21
6	3.295E-05	3.128E-05	0.000E-01	4.378E-18	4.378E-18	2.116E-21
7	5.360E-05	5.193E-05	0.000E-01	3.137E-19	3.137E-19	2.123E-21
8	7.575E-05	7.408E-05	0.000E-01	6.493E-20	6.493E-20	2.125E-21
9	1.007E-04	9.908E-05	0.000E-01	6.149E-20	6.149E-20	2.126E-21
10	1.345E-04	1.328E-04	0.000E-01	5.681E-20	5.681E-20	2.129E-21
11	1.770E-04	1.753E-04	0.000E-01	5.717E-20	5.717E-20	2.131E-21
12	2.370E-04	2.353E-04	0.000E-01	5.715E-20	5.715E-20	2.136E-21
13	3.480E-04	3.463E-04	0.000E-01	5.450E-20	5.450E-20	2.144E-21
14	5.860E-04	5.843E-04	0.000E-01	5.023E-20	5.023E-20	2.160E-21
15	1.165E-03	1.163E-03	0.000E-01	4.539E-20	4.539E-20	2.198E-21
16	2.790E-03	2.788E-03	0.000E-01	3.958E-20	3.958E-20	2.294E-21
17	1.100E-02	1.100E-02	0.000E-01	2.998E-20	2.998E-20	2.713E-21
18	3.700E-02	3.700E-02	0.000E-01	1.593E-20	1.593E-20	3.319E-21
19	7.800E-02	7.800E-02	0.000E-01	6.323E-21	6.323E-21	3.597E-21
20	2.080E-01	2.080E-01	0.000E-01	1.308E-21	1.308E-21	3.879E-21
21	6.580E-01	6.580E-01	0.000E-01	4.744E-23	4.744E-23	3.912E-21
22	1.500E+00	1.497E+00	0.000E-01	1.528E-22	1.528E-22	4.064E-21

```
* * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * *
```

TDATR SAMPLE PROBLEM 2 - OUTPUT (Cont'd)

SECONDARY GAMMA SILICON DOSE (RAD/SEC)

	ABSOLUTE TIME	LOCAL TIME	UNCOLLIDED	SCATTERED	TOTAL	CUMULATIVE
3	3.700E-06	2.032E-06	0.000E-01	1.824E-16	1.824E-16	6.930E-22
4	9.450E-06	7.782E-06	0.000E-01	1.256E-16	1.256E-16	1.660E-21
5	1.850E-05	1.683E-05	0.000E-01	4.327E-17	4.327E-17	2.110E-21
6	3.295E-05	3.128E-05	0.000E-01	4.632E-18	4.632E-18	2.196E-21
7	5.360E-05	5.193E-05	0.000E-01	3.286E-19	3.286E-19	2.203E-21
8	7.575E-05	7.408E-05	0.000E-01	6.700E-20	6.700E-20	2.205E-21
9	1.007E-04	9.908E-05	0.000E-01	6.232E-20	6.232E-20	2.206E-21
10	1.345E-04	1.328E-04	0.000E-01	5.967E-20	5.967E-20	2.209E-21
11	1.770E-04	1.753E-04	0.000E-01	6.006E-20	6.006E-20	2.211E-21
12	2.370E-04	2.353E-04	0.000E-01	6.006E-20	6.006E-20	2.216E-21
13	3.480E-04	3.463E-04	0.000E-01	5.731E-20	5.731E-20	2.224E-21
14	5.860E-04	5.843E-04	0.000E-01	5.285E-20	5.285E-20	2.242E-21
15	1.165E-03	1.163E-03	0.000E-01	4.780E-20	4.780E-20	2.281E-21
16	2.790E-03	2.788E-03	0.000E-01	4.173E-20	4.173E-20	2.382E-21
17	1.100E-02	1.100E-02	0.000E-01	3.165E-20	3.165E-20	2.825E-21
18	3.700E-02	3.700E-02	0.000E-01	1.684E-20	1.684E-20	3.466E-21
19	7.800E-02	7.800E-02	0.000E-01	6.692E-21	6.692E-21	3.760E-21
20	2.080E-01	2.080E-01	0.000E-01	1.386E-21	1.386E-21	4.059E-21
21	6.580E-01	6.580E-01	0.000E-01	5.035E-23	5.035E-23	4.094E-21
22	1.500E+00	1.499E+00	0.000E-01	1.623E-22	1.623E-22	4.256E-21

* *
** EXECUTION COMPLETED

Sample Problem 3

This problem is the same as the first one except that it presents results from a 12.2-15 MeV neutron source, thus only the source and title specifications are necessary.

TDATR SAMPLE PROBLEM 3 - INPUT

```
*TITLE 14-MEV SECONDARY GAMMA RAYS AT 1KM
*N-SOURCE 0 0 1
*EXC
```

BEST AVAILABLE COPY

TDATR SAMPLE PROBLEM 3 - OUTPUT

```
TDATR PROBLEM NUMBER      3            14-MEV SECONDARY GAMMA RAYS AT 1KM

* * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * *

NEUTRON SOURCE       NORMALIZATION= 1.000E+00 NEUTRONS/KT
    YIELD= 1.000E+00 KT       TOTAL OUTPUT= 1.000E+00 NEUTRONS
    WEIGHTS - FISSION= 0.000E-01  THERMONUCLEAR= 0.000E-01  14MEV= 1.000E+00

* * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * *

TDATR PROBLEM NUMBER      3            14-MEV SECONDARY GAMMA RAYS AT 1KM

* * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * *
 GROUND LEVEL          0.000KM,    0.000GM/CM**2,   0.000KFT,   0.000MILES
*HORIZ. RANGE RH=     0.500KM,   55.583GM/CM**2,   1.640KFT,   0.311MILES
 SLANT RANGE  RS=     0.500KM,   55.583GM/CM**2,   1.640KFT,   0.311MILES
 TARGET ALT.  HT=     1.000KM,  116.741GM/CM**2,   3.281KFT,   0.621MILES
 SOURCE ALT.  HS=     1.000KM,  116.741GM/CM**2,   3.281KFT,   0.621MILES
*SLANT ANGLE  AN=      0.000DEGREES (COS= 1.00000)
         *CALCULATED FROM OTHER COORDINATES

* * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * *
```

SECONDARY GAMMA TISSUE DOSE (RAD/SEC)

	ABSOLUTE TIME	LOCAL TIME	UNCOLLIDED	SCATTERED	TOTAL	CUMULATIVE
3	3.700E-06	2.032E-06	0.000E-01	1.683E-15	1.683E-15	6.395E-21
4	9.450E-06	7.782E-06	0.000E-01	8.790E-16	8.790E-16	1.316E-20
5	1.850E-05	1.683E-05	0.000E-01	2.344E-16	2.344E-16	1.560E-20
6	3.295E-05	3.128E-05	0.000E-01	2.813E-17	2.813E-17	1.612E-20
7	5.360E-05	5.193E-05	0.000E-01	2.154E-18	2.154E-18	1.617E-20
8	7.575E-05	7.408E-05	0.000E-01	1.779E-19	1.779E-19	1.617E-20
9	1.007E-04	9.908E-05	0.000E-01	2.350E-20	2.350E-20	1.618E-20
10	1.345E-04	1.328E-04	0.000E-01	1.923E-20	1.923E-20	1.618E-20
11	1.770E-04	1.753E-04	0.000E-01	1.897E-20	1.897E-20	1.618E-20
12	2.370E-04	2.353E-04	0.000E-01	1.861E-20	1.861E-20	1.618E-20
13	3.480E-04	3.463E-04	0.000E-01	1.718E-20	1.718E-20	1.618E-20
14	5.860E-04	5.843E-04	0.000E-01	1.515E-20	1.515E-20	1.619E-20
15	1.165E-03	1.163E-03	0.000E-01	1.302E-20	1.302E-20	1.620E-20
16	2.790E-03	2.788E-03	0.000E-01	1.101E-20	1.101E-20	1.622E-20
17	1.100E-02	1.100E-02	0.000E-01	8.158E-21	8.158E-21	1.634E-20
18	3.700E-02	3.700E-02	0.000E-01	4.361E-21	4.361E-21	1.650E-20
19	7.800E-02	7.800E-02	0.000E-01	1.748E-21	1.748E-21	1.658E-20
20	2.080E-01	2.080E-01	0.000E-01	3.631E-22	3.631E-22	1.666E-20
21	6.580E-01	6.580E-01	0.000E-01	1.335E-23	1.335E-23	1.667E-20
22	1.500E+00	1.499E+00	0.000E-01	4.443E-23	4.443E-23	1.671E-20

* *

TDATR SAMPLE PROBLEM 3 - OUTPUT (Cont'd)

SECONDARY GAMMA SILICON DOSE (RAD/SEC)

	ABSOLUTE TIME	LOCAL TIME	UNCOLLIDED	SCATTERED	TOTAL	CUMULATIVE
3	3.700E-06	2.032E-06	0.000E-01	1.721E-15	1.721E-15	6.539E-21
4	9.450E-06	7.782E-06	0.000E-01	9.326E-16	9.326E-16	1.372E-20
5	1.850E-05	1.683E-05	0.000E-01	2.540E-16	2.540E-16	1.636E-20
6	3.295E-05	3.128E-05	0.000E-01	3.075E-17	3.075E-17	1.693E-20
7	5.360E-05	5.193E-05	0.000E-01	2.354E-18	2.354E-18	1.699E-20
8	7.575E-05	7.408E-05	0.000E-01	1.933E-19	1.933E-19	1.699E-20
9	1.007E-04	9.908E-05	0.000E-01	2.529E-20	2.529E-20	1.699E-20
10	1.345E-04	1.328E-04	0.000E-01	2.036E-20	2.036E-20	1.699E-20
11	1.770E-04	1.753E-04	0.000E-01	2.008E-20	2.008E-20	1.699E-20
12	2.370E-04	2.353E-04	0.000E-01	1.970E-20	1.970E-20	1.699E-20
13	3.480E-04	3.463E-04	0.000E-01	1.818E-20	1.818E-20	1.700E-20
14	5.860E-04	5.843E-04	0.000E-01	1.602E-20	1.602E-20	1.700E-20
15	1.165E-03	1.163E-03	0.000E-01	1.376E-20	1.376E-20	1.701E-20
16	2.790E-03	2.788E-03	0.000E-01	1.163E-20	1.163E-20	1.704E-20
17	1.100E-02	1.100E-02	0.000E-01	8.608E-21	8.608E-21	1.716E-20
18	3.700E-02	3.700E-02	0.000E-01	4.597E-21	4.597E-21	1.734E-20
19	7.800E-02	7.800E-02	0.000E-01	1.842E-21	1.842E-21	1.742E-20
20	2.080E-01	2.080E-01	0.000E-01	3.822E-22	3.822E-22	1.750E-20
21	6.580E-01	6.580E-01	0.000E-01	1.404E-23	1.404E-23	1.751E-20
22	1.500E+00	1.499E+00	0.000E-01	4.669E-23	4.669E-23	1.756E-20

* *
** EXECUTION COMPLETED

Sample Problem 4

This example presents results due to an 8-10 MeV prompt gamma ray delta function source. The requested responses are the concrete and air dose at 1 km co-altitude with a source-target separation of 800 m. The output local time mesh is given in seconds, and it will be used for all subsequent problems.

TDATR SAMPLE PROBLEM 4 - INPUT

```
*TITLE 8-10 MEV SOURCE  PROMPT GAMMA RAYS
*HS,KM,1
*HT,KM,1
*RS 800
*G-SOURCE(1)
*G-SVAL 17*0 1
*LTIME/G/,SEC,0 1-9 2.154-9 4.64-9 1-8 2.15-8 4.64-8 1-7 2.15-7 4.64-7
 1-6 2.15-6 4.64-6 1-5
*RESP/G/(3 4)
*EXC
```

TDATR SAMPLE PROBLEM 4 - OUTPUT

```
TDATR PROBLEM NUMBER      1            8-10 MEV SOURCE  PROMPT GAMMA RAYS

* * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * *

GAMMA SOURCE      NORMALIZATION= 1.000E+00 GAMMAS/KT
    YIELD= 1.000E+00 KT       TOTAL OUTPUT= 1.000E+00 GAMMAS

TIME(SEC) /  ENERGY  1 ENERGY  2 ENERGY  3 ENERGY  4 ENERGY  5 ENERGY  6

0.0000E-01  0.000E-01 0.000E-01 0.000E-01 0.000E-01 0.000E-01 0.000E-01

* * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * *

TIME(SEC) /  ENERGY  7 ENERGY  8 ENERGY  9 ENERGY 10 ENERGY 11 ENERGY 12

0.0000E-01  0.000E-01 0.000E-01 0.000E-01 0.000E-01 0.000E-01 0.000E-01

* * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * *

TIME(SEC) /  ENERGY 13 ENERGY 14 ENERGY 15 ENERGY 16 ENERGY 17 ENERGY 18

0.0000E-01  0.000E-01 0.000E-01 0.000E-01 0.000E-01 0.000E-01 1.000E+00

* * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * *

TDATR PROBLEM NUMBER      1            8-10 MEV SOURCE  PROMPT GAMMA RAYS

* * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * *
 GROUND LEVEL        0.000KM,    0.000GM/CM**2,  0.000KFT,  0.000MILES
*HORIZ. RANGE RH=  0.800KM,  88.932GM/CM**2,  2.625KFT,  0.497MILES
 SLANT RANGE  RS=  0.800KM,  88.932GM/CM**2,  2.625KFT,  0.497MILES
 TARGET ALT.  HT=  1.000KM, 116.741GM/CM**2,  3.281KFT,  0.621MILES
 SOURCE ALT.  HS=  1.000KM, 116.741GM/CM**2,  3.281KFT,  0.621MILES
*SLANT ANGLE  AN=    0.000DEGREES (COS= 1.00000)
         *CALCULATED FROM OTHER COORDINATES

* * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * *
```

TDATR SAMPLE PROBLEM 4 - OUTPUT (Cont'd)

PROMPT GAMMA CONCRETE DOSE (RAD/SEC)

	ABSOLUTE TIME	LOCAL TIME	UNCOLLIDED	SCATTERED	TOTAL	CUMULATIVE
1	2.669E-06	5.000E-10	5.137E-12	0.000E-01	5.137E-12	5.137E-21
2	2.670E-06	1.577E-09	0.000E-01	3.229E-13	3.229E-13	5.509E-21
3	2.672E-06	3.397E-09	0.000E-01	2.306E-13	2.306E-13	6.083E-21
4	2.676E-06	7.320E-09	0.000E-01	1.341E-13	1.341E-13	6.801E-21
5	2.684E-06	1.575E-08	0.000E-01	6.624E-14	6.624E-14	7.563E-21
6	2.702E-06	3.395E-08	0.000E-01	2.856E-14	2.856E-14	8.274E-21
7	2.742E-06	7.320E-08	0.000E-01	1.131E-14	1.131E-14	8.880E-21
8	2.826E-06	1.575E-07	0.000E-01	4.322E-15	4.322E-15	9.377E-21
9	3.008E-06	3.395E-07	0.000E-01	1.699E-15	1.699E-15	9.800E-21
10	3.401E-06	7.320E-07	0.000E-01	8.530E-16	8.530E-16	1.026E-20
11	4.244E-06	1.575E-06	0.000E-01	4.857E-16	4.857E-16	1.082E-20
12	6.064E-06	3.395E-06	0.000E-01	1.876E-16	1.876E-16	1.128E-20
13	9.989E-06	7.320E-06	0.000E-01	1.526E-17	1.526E-17	1.136E-20

* *

PROMPT GAMMA AIR DOSE (RAD/SEC)

	ABSOLUTE TIME	LOCAL TIME	UNCOLLIDED	SCATTERED	TOTAL	CUMULATIVE
1	2.669E-06	5.000E-10	4.342E-12	0.000E-01	4.342E-12	4.342E-21
2	2.670E-06	1.577E-09	0.000E-01	2.821E-13	2.821E-13	4.667E-21
3	2.672E-06	3.397E-09	0.000E-01	2.035E-13	2.035E-13	5.173E-21
4	2.676E-06	7.320E-09	0.000E-01	1.205E-13	1.205E-13	5.819E-21
5	2.684E-06	1.575E-08	0.000E-01	6.084E-14	6.084E-14	6.519E-21
6	2.702E-06	3.395E-08	0.000E-01	2.696E-14	2.696E-14	7.190E-21
7	2.742E-06	7.320E-08	0.000E-01	1.089E-14	1.089E-14	7.774E-21
8	2.826E-06	1.575E-07	0.000E-01	4.145E-15	4.145E-15	8.251E-21
9	3.008E-06	3.395E-07	0.000E-01	1.500E-15	1.500E-15	8.624E-21
10	3.401E-06	7.320E-07	0.000E-01	5.193E-16	5.193E-16	8.903E-21
11	4.244E-06	1.575E-06	0.000E-01	1.666E-16	1.666E-16	9.094E-21
12	6.064E-06	3.395E-06	0.000E-01	4.260E-17	4.260E-17	9.200E-21
13	9.989E-06	7.320E-06	0.000E-01	2.677E-18	2.677E-18	9.215E-21

* *
** EXECUTION COMPLETED

Sample Problem 5

This example is similar to sample problem 4 with the only difference being that the source gamma is in the 1-1.33 MeV source bin, and only the source and title specifications are needed.

TDATR SAMPLE PROBLEM 5 - INPUT

```
*TITLE 1-1.33 MEV SOURCE PROMPT GAMMA RAYS
*G-SVAL 8*0 1 9*0
*EXC
```

TDATR SAMPLE PROBLEM 5 - OUTPUT

```
TDATR PROBLEM NUMBER      2            1-1.33 MEV SOURCE PROMPT GAMMA RAYS

* * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * *

GAMMA SOURCE       NORMALIZATION= 1.000E+00 GAMMAS/KT
    YIELD= 1.000E+00 KT       TOTAL OUTPUT= 1.000E+00 GAMMAS

TIME(SEC) /  ENERGY  1 ENERGY  2 ENERGY  3 ENERGY  4 ENERGY  5 ENERGY  6

0.0000E-01  0.000E-01 0.000E-01 0.000E-01 0.000E-01 0.000E-01 0.000E-01

* * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * *

TIME(SEC) /  ENERGY  7 ENERGY  8 ENERGY  9 ENERGY 10 ENERGY 11 ENERGY 12

0.0000E-01  0.000E-01 0.000E-01 1.000E+00 0.000E-01 0.000E-01 0.000E-01

* * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * *

TIME(SEC) /  ENERGY 13 ENERGY 14 ENERGY 15 ENERGY 16 ENERGY 17 ENERGY 18

0.0000E-01  0.000E-01 0.000E-01 0.000E-01 0.000E-01 0.000E-01 0.000E-01

* * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * *

TDATR PROBLEM NUMBER      2            1-1.33 MEV SOURCE PROMPT GAMMA RAYS

* * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * *
 GROUND LEVEL          0.000KM,    0.000GM/CM**2,  0.000KFT,   0.000MILES
*HORIZ. RANGE RH=   0.800KM,   88.932GM/CM**2,  2.625KFT,   0.497MILES
 SLANT RANGE  RS=   0.800KM,   88.932GM/CM**2,  2.625KFT,   0.497MILES
 TARGET ALT.  HT=   1.000KM,  116.741GM/CM**2,  3.281KFT,   0.621MILES
 SOURCE ALT.  HS=   1.000KM,  116.741GM/CM**2,  3.281KFT,   0.621MILES
*SLANT ANGLE  AN=     0.000DEGREES (COS= 1.00000)
        *CALCULATED FROM OTHER COORDINATES

* * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * *
```

TDATR SAMPLE PROBLEM 5 - OUTPUT (Cont'd)

PROMPT GAMMA CONCRETE DOSE (RAD/SEC)

	ABSOLUTE TIME	LOCAL TIME	UNCOLLIDED	SCATTERED	TOTAL	CUMULATIVE
1	2.669E-06	5.000E-10	3.308E-14	0.000E-01	3.308E-14	3.308E-23
2	2.670E-06	1.577E-09	0.000E-01	1.214E-15	1.214E-15	3.448E-23
3	2.672E-06	3.397E-09	0.000E-01	2.120E-15	2.120E-15	3.975E-23
4	2.676E-06	7.320E-09	0.000E-01	1.666E-15	1.666E-15	4.868E-23
5	2.684E-06	1.575E-08	0.000E-01	1.278E-15	1.278E-15	6.338E-23
6	2.702E-06	3.395E-08	0.000E-01	7.172E-16	7.172E-16	8.124E-23
7	2.742E-06	7.320E-08	0.000E-01	6.023E-16	6.023E-16	1.135E-22
8	2.826E-06	1.575E-07	0.000E-01	3.238E-16	3.238E-16	1.508E-22
9	3.008E-06	3.395E-07	0.000E-01	2.282E-16	2.282E-16	2.076E-22
10	3.401E-06	7.320E-07	0.000E-01	2.079E-16	2.079E-16	3.190E-22
11	4.244E-06	1.575E-06	0.000E-01	1.548E-16	1.548E-16	4.970E-22
12	6.064E-06	3.395E-06	0.000E-01	5.031E-17	5.031E-17	6.223E-22
13	9.989E-06	7.320E-06	0.000E-01	5.111E-18	5.111E-18	6.497E-22

* *

PROMPT GAMMA AIR DOSE (RAD/SEC)

	ABSOLUTE TIME	LOCAL TIME	UNCOLLIDED	SCATTERED	TOTAL	CUMULATIVE
1	2.669E-06	5.000E-10	3.308E-14	0.000E-01	3.308E-14	3.308E-23
2	2.670E-06	1.577E-09	0.000E-01	1.212E-15	1.212E-15	3.448E-23
3	2.672E-06	3.397E-09	0.000E-01	2.117E-15	2.117E-15	3.974E-23
4	2.676E-06	7.320E-09	0.000E-01	1.661E-15	1.661E-15	4.865E-23
5	2.684E-06	1.575E-08	0.000E-01	1.271E-15	1.271E-15	6.326E-23
6	2.702E-06	3.395E-08	0.000E-01	7.073E-16	7.073E-16	8.088E-23
7	2.742E-06	7.320E-08	0.000E-01	5.870E-16	5.870E-16	1.123E-22
8	2.826E-06	1.575E-07	0.000E-01	3.024E-16	3.024E-16	1.471E-22
9	3.008E-06	3.395E-07	0.000E-01	1.755E-16	1.755E-16	1.908E-22
10	3.401E-06	7.320E-07	0.000E-01	1.037E-16	1.037E-16	2.464E-22
11	4.244E-06	1.575E-06	0.000E-01	4.046E-17	4.046E-17	2.929E-22
12	6.064E-06	3.395E-06	0.000E-01	1.006E-17	1.006E-17	3.180E-22
13	9.989E-06	7.320E-06	0.000E-01	8.261E-19	8.261E-19	3.224E-22

* *

** EXECUTION COMPLETED

Sample Problem 6

This problem is also similar to sample problem 4 with the exception that the prompt gamma ray source is a fission delta function source. The 18 source values are entered via the *G-SVAL command.

TDATR SAMPLE PROBLEM 6 - INPUT

```
*TITLE FISSION SOURCE PROMPT GAMMA RAYS
*G-SVAL 3.084-2 1.355-2 8.164-2 6.872-2 8.678-2 .17681 .14017 .10042 .10729
 6.183-2 3.935-2 3.756-2 2.233-2 2.116-2 7.483-3 3.23-3 6.79-4 1.58-4
*EXC
```

TDATR SAMPLE PROBLEM 6 - OUTPUT

```
TDATR PROBLEM NUMBER      3            FISSION SOURCE PROMPT GAMMA RAYS

* * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * *

GAMMA SOURCE      NORMALIZATION= 1.000E+00 GAMMAS/KT
    YIELD= 1.000E+00 KT      TOTAL OUTPUT= 1.000E+00 GAMMAS

TIME(SEC) /  ENERGY  1 ENERGY  2 ENERGY  3 ENERGY  4 ENERGY  5 ENERGY  6

0.0000E-01  3.084E-02 1.355E-02 8.164E-02 6.872E-02 8.678E-02 1.768E-01

* * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * *

TIME(SEC) /  ENERGY  7 ENERGY  8 ENERGY  9 ENERGY 10 ENERGY 11 ENERGY 12

0.0000E-01  1.402E-01 1.004E-01 1.073E-01 6.183E-02 3.935E-02 3.756E-02

* * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * *

TIME(SEC) /  ENERGY 13 ENERGY 14 ENERGY 15 ENERGY 16 ENERGY 17 ENERGY 18

0.0000E-01  2.233E-02 2.116E-02 7.483E-03 3.230E-03 6.790E-04 1.580E-04

* * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * *

TDATR PROBLEM NUMBER      3            FISSION SOURCE PROMPT GAMMA RAYS

* * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * *
 GROUND LEVEL        0.000KM,     0.000GM/CM**2,   0.000KFT,   0.000MILES
*HORIZ. RANGE RH=   0.800KM,   88.932GM/CM**2,   2.625KFT,   0.497MILES
 SLANT RANGE  RS=   0.800KM,   88.932GM/CM**2,   2.625KFT,   0.497MILES
 TARGET ALT.  HT=   1.000KM,  116.741GM/CM**2,   3.281KFT,   0.621MILES
 SOURCE ALT.  HS=   1.000KM,  116.741GM/CM**2,   3.281KFT,   0.621MILES
*SLANT ANGLE  AN=    0.000DEGREES (COS= 1.00000)
          *CALCULATED FROM OTHER COORDINATES

* * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * *
```

BEST AVAILABLE COPY

TDATR SAMPLE PROBLEM 6 - OUTPUT (Cont'd)

PROMPT GAMMA CONCRETE DOSE (RAD/SEC)

	ABSOLUTE TIME	LOCAL TIME	UNCOLLIDED	SCATTERED	TOTAL	CUMULATIVE
1	2.669E-06	5.000E-10	7.293E-14	0.000E-01	7.293E-14	7.293E-23
2	2.670E-06	1.577E-09	0.000E-01	6.566E-15	6.566E-15	8.051E-23
3	2.672E-06	3.397E-09	0.000E-01	5.636E-15	5.636E-15	9.452E-23
4	2.676E-06	7.320E-09	0.000E-01	3.641E-15	3.641E-15	1.140E-22
5	2.684E-06	1.575E-08	0.000E-01	2.321E-15	2.321E-15	1.407E-22
6	2.702E-06	3.395E-08	0.000E-01	1.266E-15	1.266E-15	1.722E-22
7	2.742E-06	7.320E-08	0.000E-01	6.744E-16	6.744E-16	2.084E-22
8	2.826E-06	1.575E-07	0.000E-01	3.357E-16	3.357E-16	2.470E-22
9	3.008E-06	3.395E-07	0.000E-01	1.750E-16	1.750E-16	2.906E-22
10	3.401E-06	7.320E-07	0.000E-01	1.128E-16	1.128E-16	3.511E-22
11	4.244E-06	1.575E-06	0.000E-01	7.152E-17	7.152E-17	4.333E-22
12	6.064E-06	3.395E-06	0.000E-01	2.665E-17	2.665E-17	4.996E-22
13	9.989E-06	7.320E-06	0.000E-01	2.304E-18	2.304E-18	5.120E-22

* *

PROMPT GAMMA AIR DOSE (RAD/SEC)

	ABSOLUTE TIME	LOCAL TIME	UNCOLLIDED	SCATTERED	TOTAL	CUMULATIVE
1	2.669E-06	5.000E-10	6.956E-14	0.000E-01	6.956E-14	6.956E-23
2	2.670E-06	1.577E-09	0.000E-01	6.220E-15	6.220E-15	7.674E-23
3	2.672E-06	3.397E-09	0.000E-01	5.379E-15	5.379E-15	9.011E-23
4	2.676E-06	7.320E-09	0.000E-01	3.503E-15	3.503E-15	1.089E-22
5	2.684E-06	1.575E-08	0.000E-01	2.258E-15	2.258E-15	1.348E-22
6	2.702E-06	3.395E-08	0.000E-01	1.240E-15	1.240E-15	1.657E-22
7	2.742E-06	7.320E-08	0.000E-01	6.591E-16	6.591E-16	2.010E-22
8	2.826E-06	1.575E-07	0.000E-01	3.177E-16	3.177E-16	2.376E-22
9	3.008E-06	3.395E-07	0.000E-01	1.418E-16	1.418E-16	2.729E-22
10	3.401E-06	7.320E-07	0.000E-01	5.904E-17	5.904E-17	3.045E-22
11	4.244E-06	1.575E-06	0.000E-01	2.102E-17	2.102E-17	3.287E-22
12	6.064E-06	3.395E-06	0.000E-01	5.485E-18	5.485E-18	3.424E-22
13	9.989E-06	7.320E-06	0.000E-01	3.883E-19	3.883E-19	3.444E-22

* *

** EXECUTION COMPLETED

AD-A053 464 SCIENCE APPLICATIONS INC LA JOLLA CALIF F/G 20/8

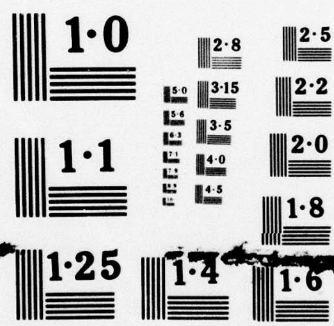
TIME DEPENDENT AIR TRANSPORT OF RADIATION (TDATR).(U)

JAN 76 L HUSZAR, W A WOOLSON DNA001-74-C-0027

UNCLASSIFIED SAI-76-562-LJ DNA-4061F NL

2 OF 2
ADA
053464

END
DATE
FILMED
6-78
DDC



NATIONAL BUREAU OF STANDARDS
MICROCOPY RESOLUTION TEST CHART

Sample Problem 7

The geometry and response configurations for this problem are the same as for sample problem 4. The source is a time dependent Gaussian in the 8-10 MeV source group. The parameters for the Gaussian are: the mean is at 10 shakes the amplitude is 1 MeV/second and the full-width-at-half-maximum (FWHM) is two shakes. The source time bins are given by the *G-TIME command in shakes (the default unit).

TDATR SAMPLE PROBLEM 7 - INPUT

```
*TITLE GAUSSIAN SOURCE PROMPT GAMMA RAYS
*G-SOURCE(2)
*G-SVAL 17*0 1
*G-TIME 0 2 4 6 8 9 10 11 12 14 16 20 30
*G-GAUSS 10 1 2
*EXC
```

TDATR SAMPLE PROBLEM 7 - OUTPUT

TDATR PROBLEM NUMBER 4 GAUSSIAN SOURCE PROMPT GAMMA RAYS

* *

GAMMA SOURCE NORMALIZATION= 2.361E-01 GAMMAS/KT
YIELD= 1.000E+00 KT TOTAL OUTPUT= 2.361E-01 GAMMAS

TIME(SEC) / ENERGY	1 ENERGY	2 ENERGY	3 ENERGY	4 ENERGY	5 ENERGY	6
0.0000E-01	0.000E-01	0.000E-01	0.000E-01	0.000E-01	0.000E-01	0.000E-01
2.0000E-08	0.000E-01	0.000E-01	0.000E-01	0.000E-01	0.000E-01	0.000E-01
4.0000E-08	0.000E-01	0.000E-01	0.000E-01	0.000E-01	0.000E-01	0.000E-01
6.0000E-08	0.000E-01	0.000E-01	0.000E-01	0.000E-01	0.000E-01	0.000E-01
8.0000E-08	0.000E-01	0.000E-01	0.000E-01	0.000E-01	0.000E-01	0.000E-01
9.0000E-08	0.000E-01	0.000E-01	0.000E-01	0.000E-01	0.000E-01	0.000E-01
1.0000E-07	0.000E-01	0.000E-01	0.000E-01	0.000E-01	0.000E-01	0.000E-01
1.1000E-07	0.000E-01	0.000E-01	0.000E-01	0.000E-01	0.000E-01	0.000E-01
1.2000E-07	0.000E-01	0.000E-01	0.000E-01	0.000E-01	0.000E-01	0.000E-01
1.4000E-07	0.000E-01	0.000E-01	0.000E-01	0.000E-01	0.000E-01	0.000E-01
1.6000E-07	0.000E-01	0.000E-01	0.000E-01	0.000E-01	0.000E-01	0.000E-01
2.0000E-07	0.000E-01	0.000E-01	0.000E-01	0.000E-01	0.000E-01	0.000E-01
3.0000E-07	0.000E-01	0.000E-01	0.000E-01	0.000E-01	0.000E-01	0.000E-01

* *

TIME(SEC) / ENERGY	7 ENERGY	8 ENERGY	9 ENERGY	10 ENERGY	11 ENERGY	12
0.0000E-01	0.000E-01	0.000E-01	0.000E-01	0.000E-01	0.000E-01	0.000E-01
2.0000E-08	0.000E-01	0.000E-01	0.000E-01	0.000E-01	0.000E-01	0.000E-01
4.0000E-08	0.000E-01	0.000E-01	0.000E-01	0.000E-01	0.000E-01	0.000E-01
6.0000E-08	0.000E-01	0.000E-01	0.000E-01	0.000E-01	0.000E-01	0.000E-01
8.0000E-08	0.000E-01	0.000E-01	0.000E-01	0.000E-01	0.000E-01	0.000E-01
9.0000E-08	0.000E-01	0.000E-01	0.000E-01	0.000E-01	0.000E-01	0.000E-01
1.0000E-07	0.000E-01	0.000E-01	0.000E-01	0.000E-01	0.000E-01	0.000E-01
1.1000E-07	0.000E-01	0.000E-01	0.000E-01	0.000E-01	0.000E-01	0.000E-01
1.2000E-07	0.000E-01	0.000E-01	0.000E-01	0.000E-01	0.000E-01	0.000E-01
1.4000E-07	0.000E-01	0.000E-01	0.000E-01	0.000E-01	0.000E-01	0.000E-01
1.6000E-07	0.000E-01	0.000E-01	0.000E-01	0.000E-01	0.000E-01	0.000E-01
2.0000E-07	0.000E-01	0.000E-01	0.000E-01	0.000E-01	0.000E-01	0.000E-01
3.0000E-07	0.000E-01	0.000E-01	0.000E-01	0.000E-01	0.000E-01	0.000E-01

* *

TIME(SEC) /	ENERGY 13	ENERGY 14	ENERGY 15	ENERGY 16	ENERGY 17	ENERGY 18
0.0000E-01	0.000E-01	0.000E-01	0.000E-01	0.000E-01	0.000E-01	8.763E-32
2.0000E-08	0.000E-01	0.000E-01	0.000E-01	0.000E-01	0.000E-01	6.022E-21
4.0000E-08	0.000E-01	0.000E-01	0.000E-01	0.000E-01	0.000E-01	1.617E-12
6.0000E-08	0.000E-01	0.000E-01	0.000E-01	0.000E-01	0.000E-01	1.695E-06
8.0000E-08	0.000E-01	0.000E-01	0.000E-01	0.000E-01	0.000E-01	6.944E-03
9.0000E-08	0.000E-01	0.000E-01	0.000E-01	0.000E-01	0.000E-01	5.556E-02
1.0000E-07	0.000E-01	0.000E-01	0.000E-01	0.000E-01	0.000E-01	1.111E-01
1.1000E-07	0.000E-01	0.000E-01	0.000E-01	0.000E-01	0.000E-01	5.556E-02
1.2000E-07	0.000E-01	0.000E-01	0.000E-01	0.000E-01	0.000E-01	6.944E-03
1.4000E-07	0.000E-01	0.000E-01	0.000E-01	0.000E-01	0.000E-01	1.695E-06
1.6000E-07	0.000E-01	0.000E-01	0.000E-01	0.000E-01	0.000E-01	1.617E-12
2.0000E-07	0.000E-01	0.000E-01	0.000E-01	0.000E-01	0.000E-01	8.763E-32
3.0000E-07	0.000E-01	0.000E-01	0.000E-01	0.000E-01	0.000E-01	0.000E-01

```
* * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * *

TDATR PROBLEM NUMBER      4            GAUSSIAN SOURCE PROMPT GAMMA RAYS

* * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * *
 GROUND LEVEL         0.000KM,    0.000GM/CM**2,  0.000KFT,  0.000MILES
*HORIZ. RANGE RH=   0.800KM,   88.932GM/CM**2,  2.625KFT,  0.497MILES
 SLANT RANGE   RS=   0.800KM,   88.932GM/CM**2,  2.625KFT,  0.497MILES
 TARGET ALT.   HT=   1.000KM,  116.741GM/CM**2,  3.281KFT,  0.621MILES
 SOURCE ALT.   HS=   1.000KM,  116.741GM/CM**2,  3.281KFT,  0.621MILES
*SLANT ANGLE   AN=    0.000DEGREES (COS= 1.00000)
        *CALCULATED FROM OTHER COORDINATES

* * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * *
```

PROMPT GAMMA CONCRETE DOSE (RAD/SEC)

	ABSOLUTE TIME	LOCAL TIME	UNCOLLIDED	SCATTERED	TOTAL	CUMULATIVE
1	2.669E-06	5.000E-10	0.000E-01	0.000E-01	0.000E-01	0.000E-01
2	2.670E-06	1.577E-09	7.196E-24	0.000E-01	7.196E-24	8.304E-33
3	2.672E-06	3.397E-09	1.428E-14	0.000E-01	1.428E-14	3.551E-23
4	2.676E-06	7.320E-09	2.052E-13	0.000E-01	2.052E-13	1.135E-21
5	2.684E-06	1.575E-08	2.792E-14	0.000E-01	2.792E-14	1.456E-21
6	2.702E-06	3.395E-08	4.267E-19	4.605E-35	4.267E-19	1.457E-21
7	2.742E-06	7.320E-08	0.000E-01	6.441E-28	6.441E-28	1.457E-21
8	2.826E-06	1.575E-07	0.000E-01	2.615E-22	2.615E-22	1.457E-21
9	3.008E-06	3.395E-07	0.000E-01	3.614E-28	3.614E-28	1.457E-21
10	3.401E-06	7.320E-07	0.000E-01	0.000E-01	0.000E-01	1.457E-21
11	4.244E-06	1.575E-06	0.000E-01	0.000E-01	0.000E-01	1.457E-21
12	6.064E-06	3.395E-06	0.000E-01	0.000E-01	0.000E-01	1.457E-21
13	9.989E-06	7.320E-06	0.000E-01	0.000E-01	0.000E-01	1.457E-21

* *

TDATR SAMPLE PROBLEM 7 - OUTPUT (Cont'd)

PROMPT GAMMA AIR DOSE (RAD/SEC)

	ABSOLUTE TIME	LOCAL TIME	UNCOLLIDED	SCATTERED	TOTAL	CUMULATIVE
1	2.669E-06	5.000E-10	0.000E-01	0.000E-01	0.000E-01	0.000E-01
2	2.670E-06	1.577E-09	6.083E-24	0.000E-01	6.083E-24	7.020E-33
3	2.672E-06	3.397E-09	1.207E-14	0.000E-01	1.207E-14	3.002E-23
4	2.676E-06	7.320E-09	1.735E-13	0.000E-01	1.735E-13	9.598E-22
5	2.684E-06	1.575E-08	2.360E-14	0.000E-01	2.360E-14	1.231E-21
6	2.702E-06	3.395E-08	3.607E-19	3.986E-35	3.607E-19	1.231E-21
7	2.742E-06	7.320E-08	0.000E-01	5.634E-28	5.634E-28	1.231E-21
8	2.826E-06	1.575E-07	0.000E-01	2.317E-22	2.317E-22	1.231E-21
9	3.008E-06	3.395E-07	0.000E-01	3.485E-28	3.485E-28	1.231E-21
10	3.401E-06	7.320E-07	0.000E-01	0.000E-01	0.000E-01	1.231E-21
11	4.244E-06	1.575E-06	0.000E-01	0.000E-01	0.000E-01	1.231E-21
12	6.064E-06	3.395E-06	0.000E-01	0.000E-01	0.000E-01	1.231E-21
13	9.989E-06	7.320E-06	0.000E-01	0.000E-01	0.000E-01	1.231E-21

* *
** EXECUTION COMPLETED

DISTRIBUTION LIST

DEPARTMENT OF DEFENSE

Director
Armed Forces Radiobiology Research Institute
Defense Nuclear Agency
ATTN: COL McIndoe

Commandant
Armed Forces Staff College
ATTN: Commandant

Assistant to the Secretary of Defense
Atomic Energy
3 cy ATTN: Nuc. Policy Planning

Commander in Chief
U.S. European Command, JCS
ATTN: J-3
ATTN: J-5

Director
Defense Advanced Rsch. Proj. Agency
ATTN: Tactical Technology Office
ATTN: Tech. Assessment Office

Director
Defense Civil Preparedness Agency
Assistant Director for Research
ATTN: J. O. Buchanon

Defense Documentation Center
Cameron Station
12 cy ATTN: TC

Director
Defense Intelligence Agency
ATTN: DIR-4C
ATTN: DI-7
ATTN: DI-1

Director
Defense Nuclear Agency
ATTN: VLWS
ATTN: STRA
ATTN: STNA
ATTN: STSP
ATTN: STVL
ATTN: DDST
3 cy ATTN: TITL, Tech. Lib.
ATTN: TISI, Archives
ATTN: RATN

Under Secretary of Def. for Rsch. & Engrg.
ATTN: S&SS (OS)

Commander
FC, DNA
ATTN: FCPR

Director
Interservice Nuclear Weapons School
ATTN: Doc. Con.

DEPARTMENT OF DEFENSE (Continued)

Chief
Livermore Division Fld. Command, DNA
Lawrence Livermore Laboratory
ATTN: FCPRL

Chairman
Office of Joint Chiefs of Staff
ATTN: SAGA
ATTN: Technical Library

Office of Sec. of Def.
International Security Affairs
ATTN: Reg. Dir. (European)

OJCS/J-3
ATTN: J-3

OJCS/J-5
ATTN: J-5

USNMR/SHAPE
ATTN: U. S. Documents Officer

DEPARTMENT OF THE ARMY

Dep. Chief of Staff for Rsch. Dev. & Acq.
Department of the Army
ATTN: DAMA-CSM-N
ATTN: DAMA-CSM-N, LTC G. Ogden

Deputy Chief of Staff for Ops. & Plans
Department of the Army
ATTN: Tech. Advisor
ATTN: DAMO-RQS
ATTN: DAMO-SSN

Commander
Eighth U. S. Army
ATTN: CJ-CO-A

Commander
Harry Diamond Laboratories
ATTN: DELHD-RBF
ATTN: DELHD-RBG
ATTN: Chief Nuc. Vulnerability Br.
ATTN: DRXDO-TI Tech. Lib.
2 cy ATTN: DELHD-NP & DELHD-EM

Commander
Picatinny Arsenal
ATTN: T. Derosa
ATTN: ND-C-T
ATTN: SARPA-ND-C, P. Angelotti

Commander
U.S. Army Armor School
ATTN: ATSB-CTD

Director
U.S. Army Ballistic Research Labs.
ATTN: DRXBR-AM
ATTN: DRXBR-X, Julius J. Meszaros
ATTN: Tech. Lib., Edward Baicy

DEPARTMENT OF THE ARMY (Continued)

Commander
U.S. Army Comd. & General Staff College
ATTN: LTC Murry

Commander
U.S. Army Concepts Analysis Agency
ATTN: MOCA-WGP, COL Hincke

Commander in Chief
U.S. Army Europe and Seventh Army
ATTN: DCCSOPS-AFAGC-CDC
ATTN: DCSOPS-AEAGENS
ATTN: J-5

Commander
U.S. Army Forces Command
ATTN: AF-OPTS

Commandant
U.S. Army Infantry School
ATTN: ATSH-CTD

Commander
U.S. Army Materiel Dev. & Readiness Cmd.
ATTN: DRCDE-D, Lawrence Flynn

Commander
U.S. Army Missile Command
ATTN: DRCPM-PE-E, E. B. Hartwell

Commander
U.S. Army Nuclear Agency
2 cy ATTN: Commander

Commander
U.S. Army Training and Doctrine Comd.
ATTN: ATCD-CF

Commandant
U.S. Army War College
ATTN: Library

Commander
V Corps
ATTN: Commander

Commander
VII Corps
ATTN: Commander

Director
TRASANA
ATTN: R. E. Dekinder, Jr.

DEPARTMENT OF THE NAVY

Chief of Naval Material
ATTN: Mat. 0323, Irving Jaffe

Chief of Naval Operations
ATTN: OP 96
ATTN: OP 604
ATTN: OP 981

Chief of Naval Research
ATTN: Code 464, Thomas P. Quinn

Commandant of the Marine Corps
ATTN: DCS (P&O) Requirements Div.
ATTN: DCS (P&O) Strat. Plans Div.

DEPARTMENT OF THE NAVY (Continued)

Commanding General, MCDEC
ATTN: Commander

Commander
David W. Taylor Naval Ship R&D Ctr.
ATTN: Code L42-3, Library

Superintendent, Naval Academy
ATTN: Classified Library

Commander, Naval Ocean Systems Center
ATTN: Tech. Lib. for T. J. Keary

Superintendent (Code 1424)
Naval Postgraduate School
ATTN: Code 2124, Tech. Rpts. Librarian

Director, Naval Research Laboratory
ATTN: Code 2600, Tech. Lib.

Officer-in-Charge
Naval Surface Weapons Center
ATTN: Code WA50
ATTN: D. LeVine
ATTN: Code WA501, Navy Nuc. Prgms. Off.
ATTN: N. E. Scofield

President, Naval War College
ATTN: Technical Library

Commanding Officer
Naval Weapons Evaluation Facility
ATTN: J. Abbott

Commander-In-Chief
U.S. Atlantic Fleet
2 cy ATTN: JCS
ATTN: PO Box 10, Div. 20, Code 22

U.S. Pacific Fleet
ATTN: J-5
ATTN: PO Box 10, ACSI
ATTN: PO Box 10, J-216

DEPARTMENT OF THE AIR FORCE

AF Institute of Technology, AU
ATTN: ENP
ATTN: Library AFIT, Bldg. 640, Area B.

AF Weapons Laboratory, AFSC
ATTN: SAS
ATTN: DYT
ATTN: NT, Carl Baum
ATTN: SUL
ATTN: SAW

Deputy Chief of Staff
Plans and Operations
ATTN: AFXOD

Hq. USAF/RD
ATTN: RDQSM

Hq. USAF/SA
ATTN: SAMI

DEPARTMENT OF THE AIR FORCE (Continued)

Commander
Tactical Air Command
ATTN: XPS
ATTN: DCS/Plans

Commander
Strategic Air Command
ATTN: PFS

Commander in Chief
U.S. Air Forces in Europe
ATTN: XP
ATTN: DO

SAMSO/DY
ATTN: DYAE

USAF School of Aerospace Med. AFSC
ATTN: RA Chief Radiobiology Div.

DEPARTMENT OF ENERGY

Department of Energy
Controlled Thermonuclear Rsch. Div.
ATTN: Doc. Con. for Lester Price

Department of Energy
Division of Reactor Rsch. & Dev.
ATTN: Doc. Con. for Phil Hemmig

University of California
Lawrence Livermore Laboratory
ATTN: Robert Howerton, L-71
ATTN: Tech. Info., Dept. L-3
ATTN: Auston Odell, L-531
ATTN: M. Gustavson, L-21
ATTN: William J. Hogan, L-389
ATTN: George Staehle, L-24
ATTN: R. Barker, L-96 (Class L-94)

Los Alamos Scientific Laboratory
ATTN: Doc. Con. for R. Sandoval
ATTN: Doc. Con. for W. Lyons
ATTN: Doc. Con. for F. P. Young
ATTN: Doc. Con. for Donald Harris
ATTN: Doc. Con. for T. Dowler
ATTN: Doc. Con. for E. Chapin

Sandia Laboratories
ATTN: Doc. Con. for J. Kaizur
ATTN: Doc. Con. for 3141, Sandia Rpt. Coll.

Union Carbide Corporation
Holifield National Laboratory
ATTN: Doc. Con. for C. E. Clifford
ATTN: Doc. Con. for D. Bartine
ATTN: Doc. Con. for Rad. Shielding Ctr.
ATTN: Doc. Con. for Tech. Lib.

Sandia Laboratories
Livermore Laboratory
ATTN: Doc. Con. for Tech. Lib.

OTHER GOVERNMENT AGENCIES

Central Intelligence Agency
ATTN: RD/SI Rm. 5G48, Hq. Bldg. for B. Sheffneer, 2922

OTHER GOVERNMENT AGENCIES (Continued)

Department of Commerce
National Bureau of Standards
Center for Radiation Rsch.
ATTN: J. Hubell

DEPARTMENT OF DEFENSE CONTRACTORS

Aerospace Corporation
ATTN: Library

The BDM Corporation
ATTN: John Bode
ATTN: Robert Buchanan
ATTN: Charles Wasaff
ATTN: Joseph V. Braddock

General Electric Company
TEMPO-Center for Advanced Studies
ATTN: DASIAC

The Boeing Company
ATTN: A. R. Lowrey

General Research Corporation
Washington Operations
ATTN: Phil Lowry

Institute for Defense Analyses
ATTN: Ida Librarian

IRT Corporation
ATTN: Tech. Lib.

Kaman Sciences Corporation
ATTN: Frank H. Shelton

Lockheed Missiles & Space Company
ATTN: Tech. Lib.

Martin Marietta Aerospace
Orlando Division
ATTN: M. Yeager

Mathematical Applications Group Inc. (NY)
ATTN: Martin O. Cohen

McDonnell Douglas Corporation
ATTN: Tech. Library Services

Mission Research Corporation
ATTN: Dave Sowle

Pacific-Sierra Research Corp.
ATTN: Gary Lang

R&D Associates
ATTN: Harold L. Brode
ATTN: Cyrus P. Knowles
ATTN: C. MacDonald
ATTN: Richard Montgomery

Radiation Research Associates, Inc.
ATTN: Library

The Rand Corporation
ATTN: Technical Library

DEPARTMENT OF DEFENSE CONTRACTORS (Continued)

Science Applications, Inc.
Chicago Office
ATTN: Dean Kaul

Science Applications, Inc.
ATTN: L. Huszar
ATTN: W. W. Woolson
ATTN: E. A. Straker
ATTN: Marvin Drake

Science Applications, Inc.
Huntsville Division
ATTN: T. E. Albert
ATTN: Noel R. Byrn

Ship Systems, Inc.
ATTN: Brian B. Dunne

DEPARTMENT OF DEFENSE CONTRACTORS (Continued)

System Planning Corporation
ATTN: J. Douglas

System, Science and Software, Inc.
ATTN: Tech. Lib.

Tetra Tech. Inc.
ATTN: Frank Bothwell